BBC

## THE INCREDIBLE STORY OF THE BIG BANG

John Gribbin explores the epic discovery of how our Universe began *p56*

ASIA EDITION

# Knowledge

Vol. 6 Issue 7

SCIENCE • HISTORY • NATURE • FOR THE CURIOUS MIND

INCORPORATING BBC SCIENCE WORLD

# HOW SCIENCE WILL HELP YOU LIVE TO 100 AND BEYOND...

INCLUDING 5 THINGS YOU CAN DO TO EXTEND YOUR LIFE TODAY *p26*

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Has an ancient puzzle been solved at last? *p34*

### Brazilian Blues

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### The Hunt For Antigravity

Research into the phenomenon of antigravity *p46*


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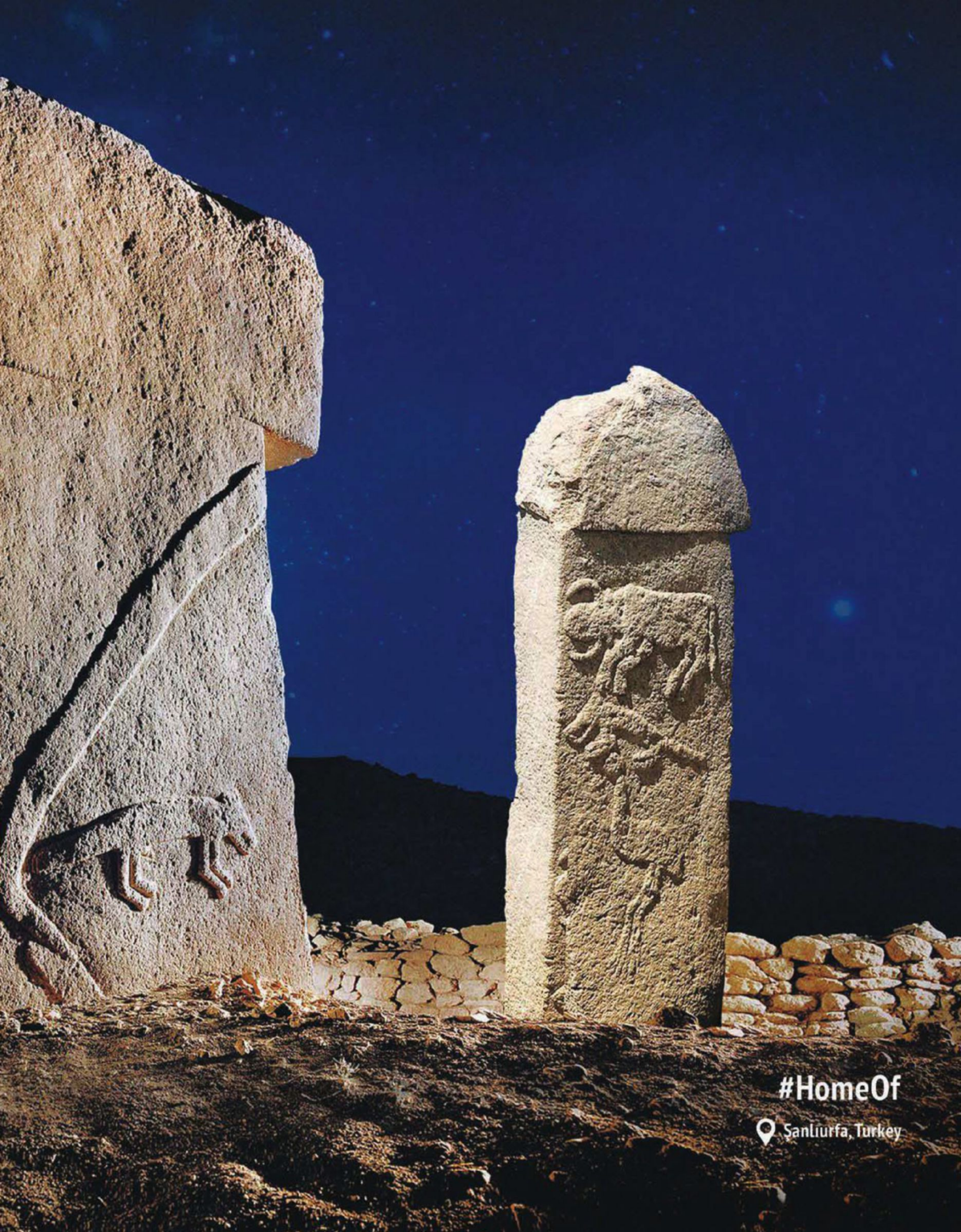
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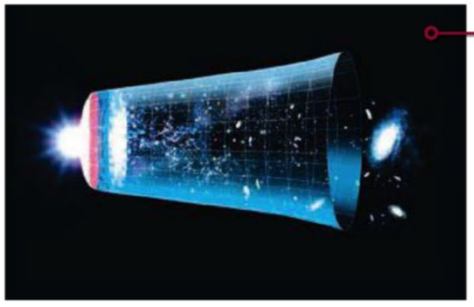

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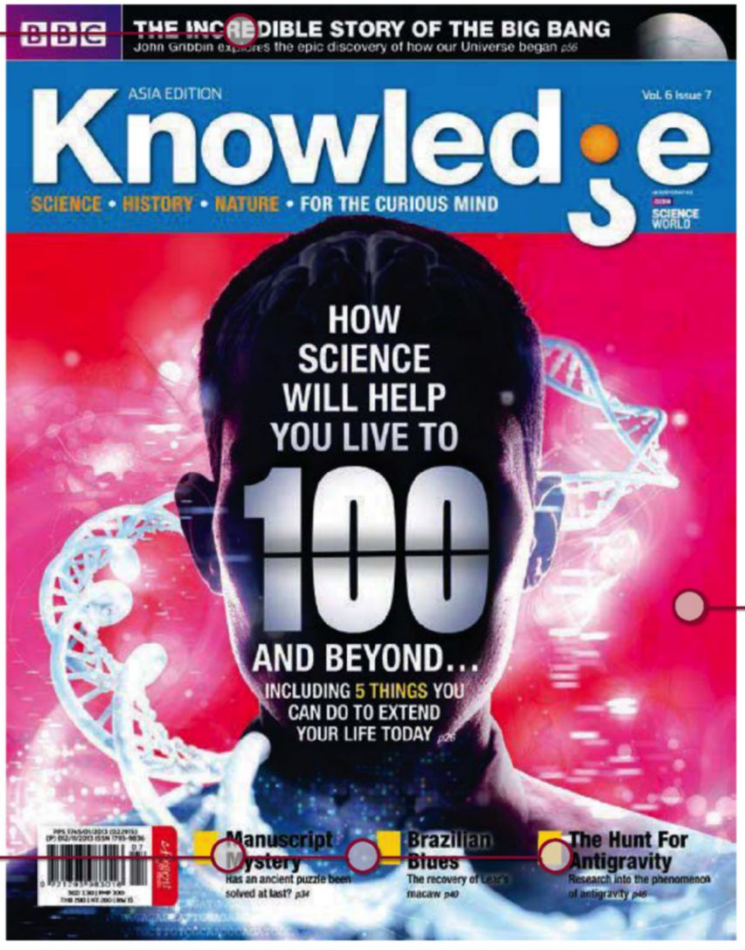


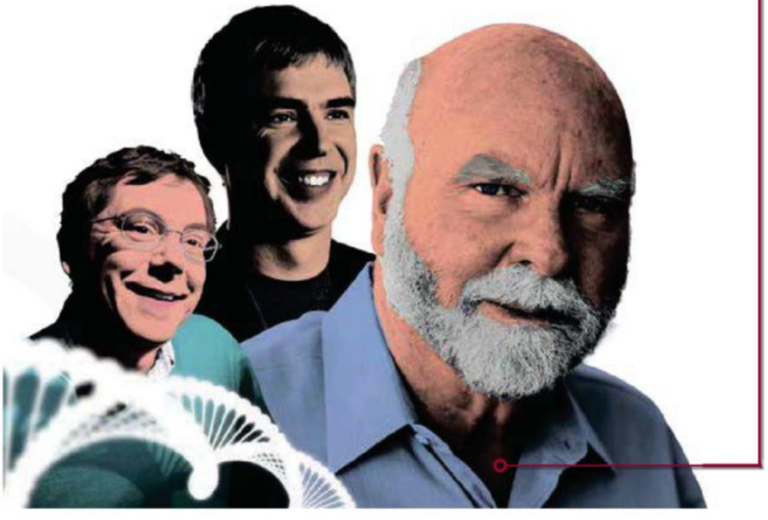

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Is longevity determined by your genes? A growing body of evidence suggests it may well be...

# ATOP

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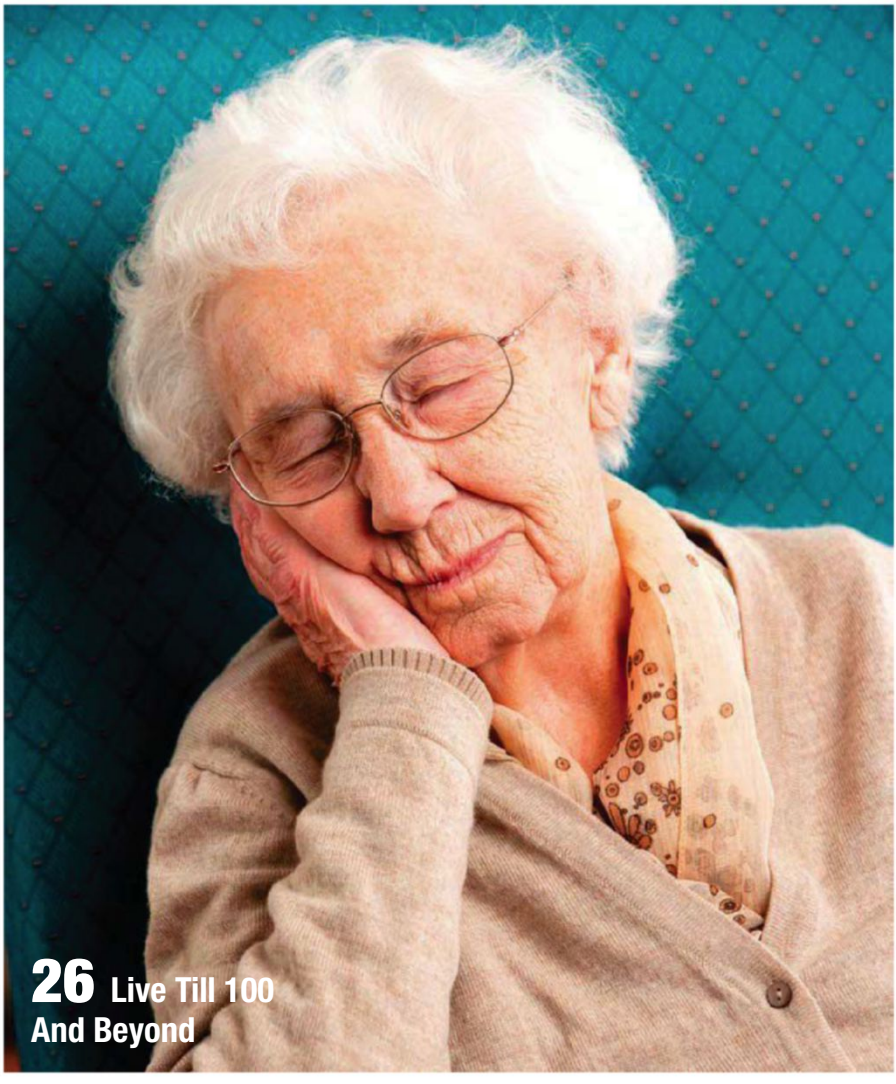








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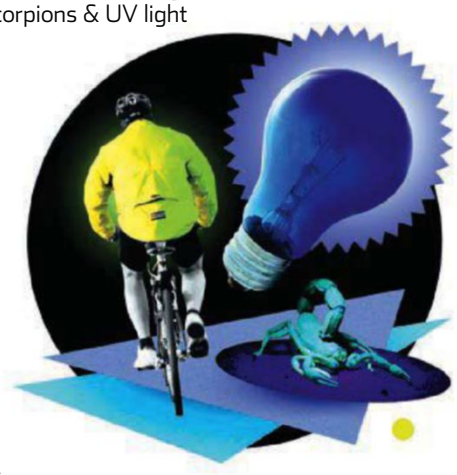



## RESOURCE

## ✉ Send us your letters

editorial-bbcknowledge@regentmedia.sg

# IS LONGEVITY A BOON OR A BANE?

Men have longed dreamed of immortality, from kings and queens to the rich and the powerful. In their pursuit of a prolonged existence, the haughty have engaged armies, even pirates, to hunt far and wide for an elixir that promises eternal youth or a potion that heals all ailments. However, little do they know, the key is to look within.

Scientists are analysing the human genome data derived from sequencing to identify and analyse the genes involved in cancer and other illnesses in the hope of finding more effective treatments.

They are also trying to understand various quirks, such as why some smokers have advanced lung cancer while others who smoke just as heavily, live to a ripe old age in relatively good health. A deeper understanding of the human gene, will give rise to customised medication or treatments that better suit a particular gene pool.

But with an ever-growing population, will we be able to sustain ourselves on the limited resources we have on Earth if we as a species are able to live longer? Is there a sweet spot for an optimum lifespan where one can enjoy longevity and yet not cause problems due to a lack of financial resources or space to live? I guess it is a conundrum that needs a solution only when we get there.

**Ben Poon**
**ben@regentmedia.sg**

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✉ We welcome your letters, while reserving the right to edit them for length and clarity. By sending us your letter you permit us to publish it in the magazine and/or on our website. We regret that we cannot always reply personally to letters.



## Experts in this issue…

### Lilian Anekwe

Lilian is the consumer health editor for the weekly journal *BMJ*. She looks at the companies aiming to help us all live to the age of 100 with the help of genetics (p26).

### Helen Czerski

In her regular column this month the oceanographer, physicist and BBC science presenter explains what high-vis cycling jackets have in common with scorpions (p25).

### John Gribbin

John is an astrophysicist and an award-winning author of popular science books including *Computing With Quantum Cats*. He uncovers the history of the Big Bang theory on p56.

### David Shukman

The BBC science editor is our new regular columnist in the Update section. This month he explores how global warming will take its toll on the world's food supply (p19).

# ✉ SEND US YOUR LETTERS

**Has something you've read in BBC Knowledge Magazine intrigued or excited you? Write in and share it with us. We'd love to hear from you and we'll publish a selection of your comments in forthcoming issues.**

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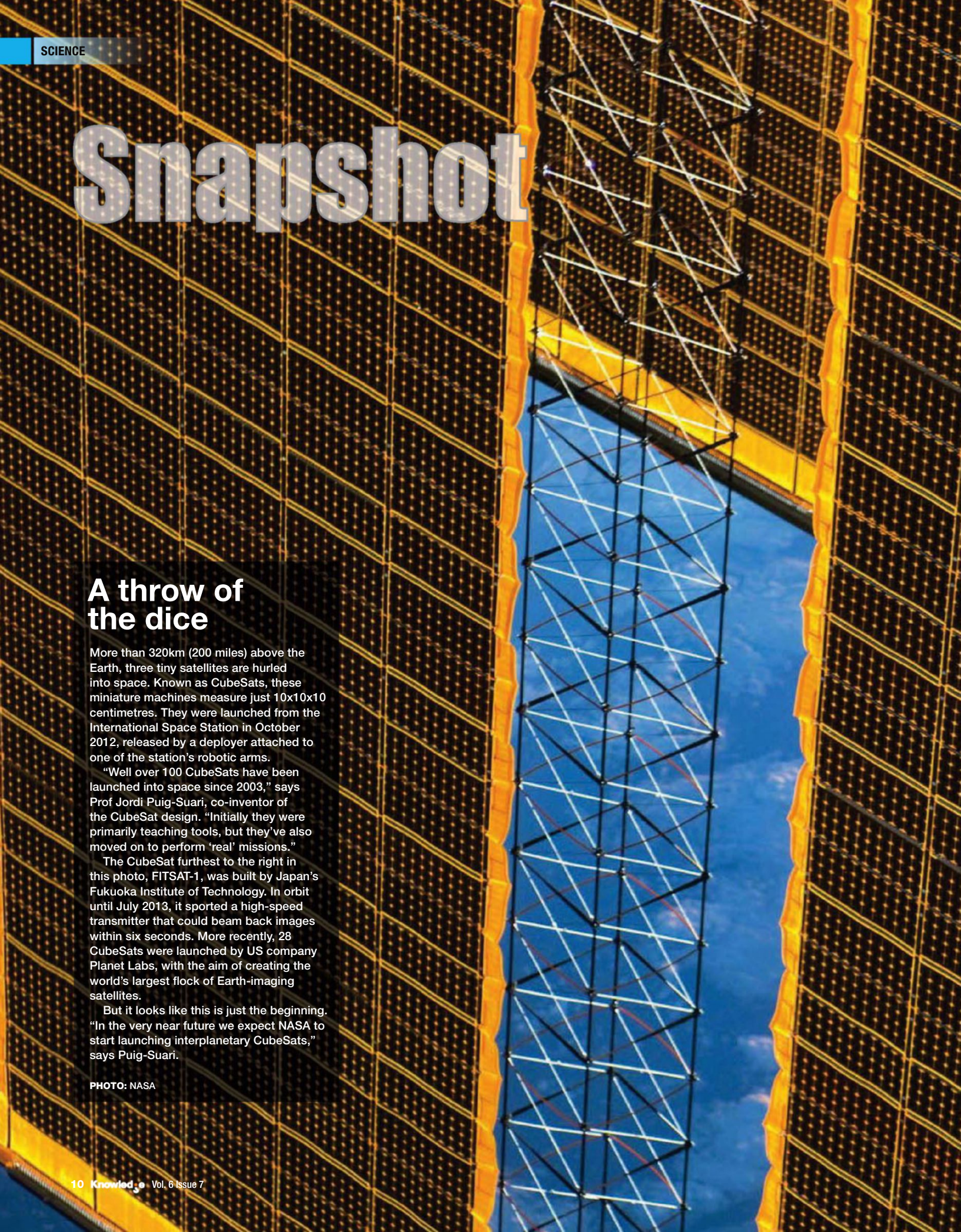
# Snapshot



## A throw of the dice

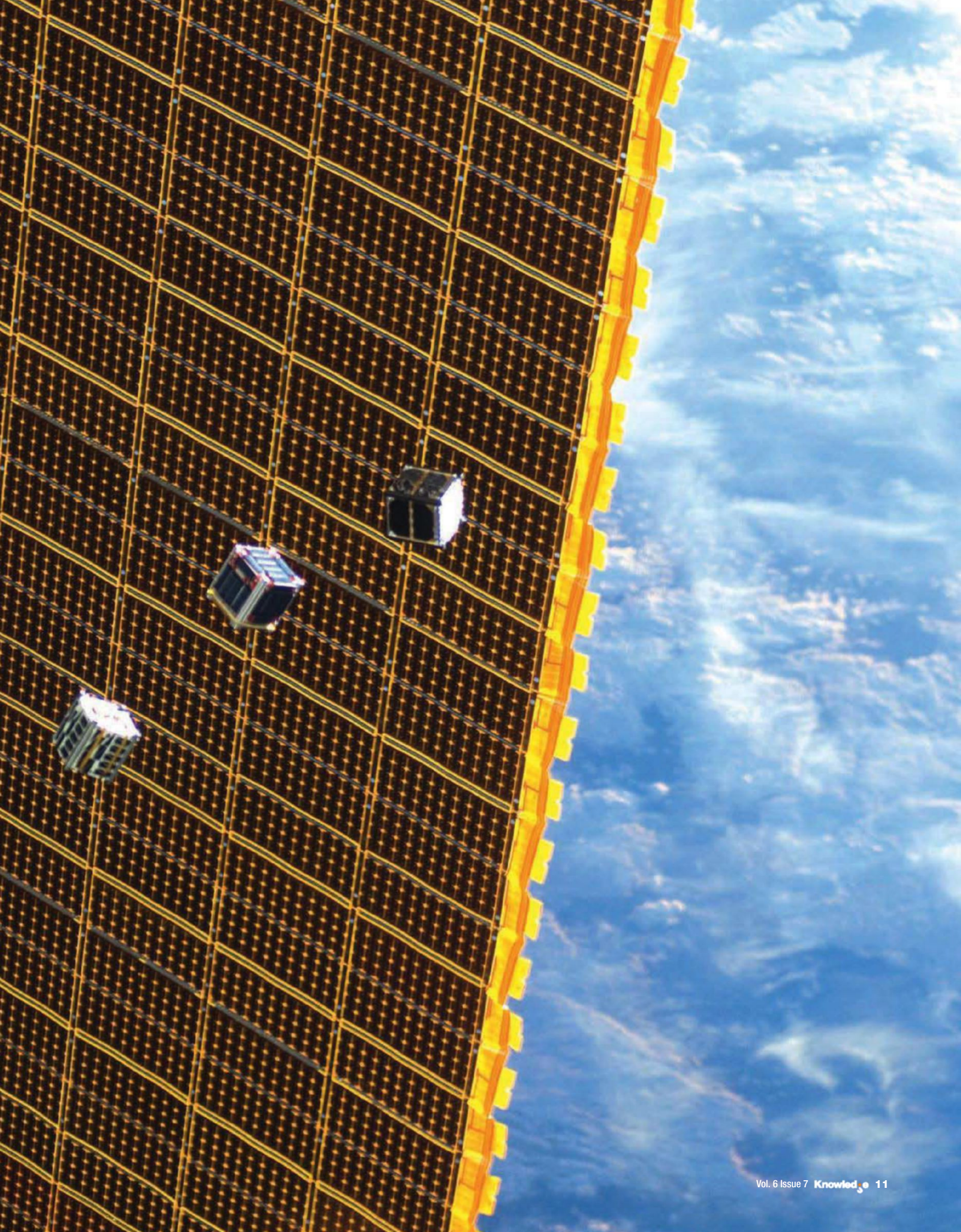
More than 320km (200 miles) above the Earth, three tiny satellites are hurled into space. Known as CubeSats, these miniature machines measure just 10x10x10 centimetres. They were launched from the International Space Station in October 2012, released by a deployer attached to one of the station's robotic arms.

"Well over 100 CubeSats have been launched into space since 2003," says Prof Jordi Puig-Suari, co-inventor of the CubeSat design. "Initially they were primarily teaching tools, but they've also moved on to perform 'real' missions."

The CubeSat furthest to the right in this photo, FITSAT-1, was built by Japan's Fukuoka Institute of Technology. In orbit until July 2013, it sported a high-speed transmitter that could beam back images within six seconds. More recently, 28 CubeSats were launched by US company Planet Labs, with the aim of creating the world's largest flock of Earth-imaging satellites.

But it looks like this is just the beginning. "In the very near future we expect NASA to start launching interplanetary CubeSats," says Puig-Suari.

**PHOTO:** NASA



# Explosive altruism

As far as taking one for the team goes, Borneo's carpenter ants are up there with the best of them. When attacked by predators, such as the larger worker ant pictured here, the bomb-like bugs grab onto their assailants and hit the self-destruct button, spraying toxic yellow glue into the air.

"Ants have a mandibular gland that is normally confined to the head," explains entomologist and BBC presenter Adam Hart. "However, in some species of carpenter ants the gland is enormous and runs down the length of the body. As a last-ditch defence mechanism, the ant can violently contract muscles that cause its abdomen and the mandibular glands to rupture. This sprays the sticky, corrosive contents all over its attacker."

This defence mechanism is known as 'autothysis' and is also seen in some species of termite.

**PHOTO:** MARK MOFFETT/FLPA


CURRENT OPERATIONS
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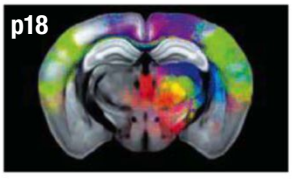
# Goddard Space Flight Centre in the 1960s

Named for American rocketry pioneer Dr. Robert H. Goddard, NASA's Goddard Space Flight Centre was established on the 1st of May 1959, as NASA's first space flight complex. When this image was taken, Goddard focused on the development of tracking and communication facilities and capabilities for both the scientific satellites and the manned space flight program. Goddard became the hub of the massive, international tracking and communications network that involved aircraft, super tankers converted into mobile communications units, and a wide diversity of ground stations. A duplicate mission control centre was also built at Goddard in case the computers at the main control room at the Johnson Space Centre in Houston, Texas failed for any reason.

**PHOTO:** NASA

# Update

THE LATEST INTELLIGENCE




**MOUSE BRAIN MAPPED OUT**

Rodent research points to better understanding of mammalian minds


**CLIMATE AND OUR FOOD**

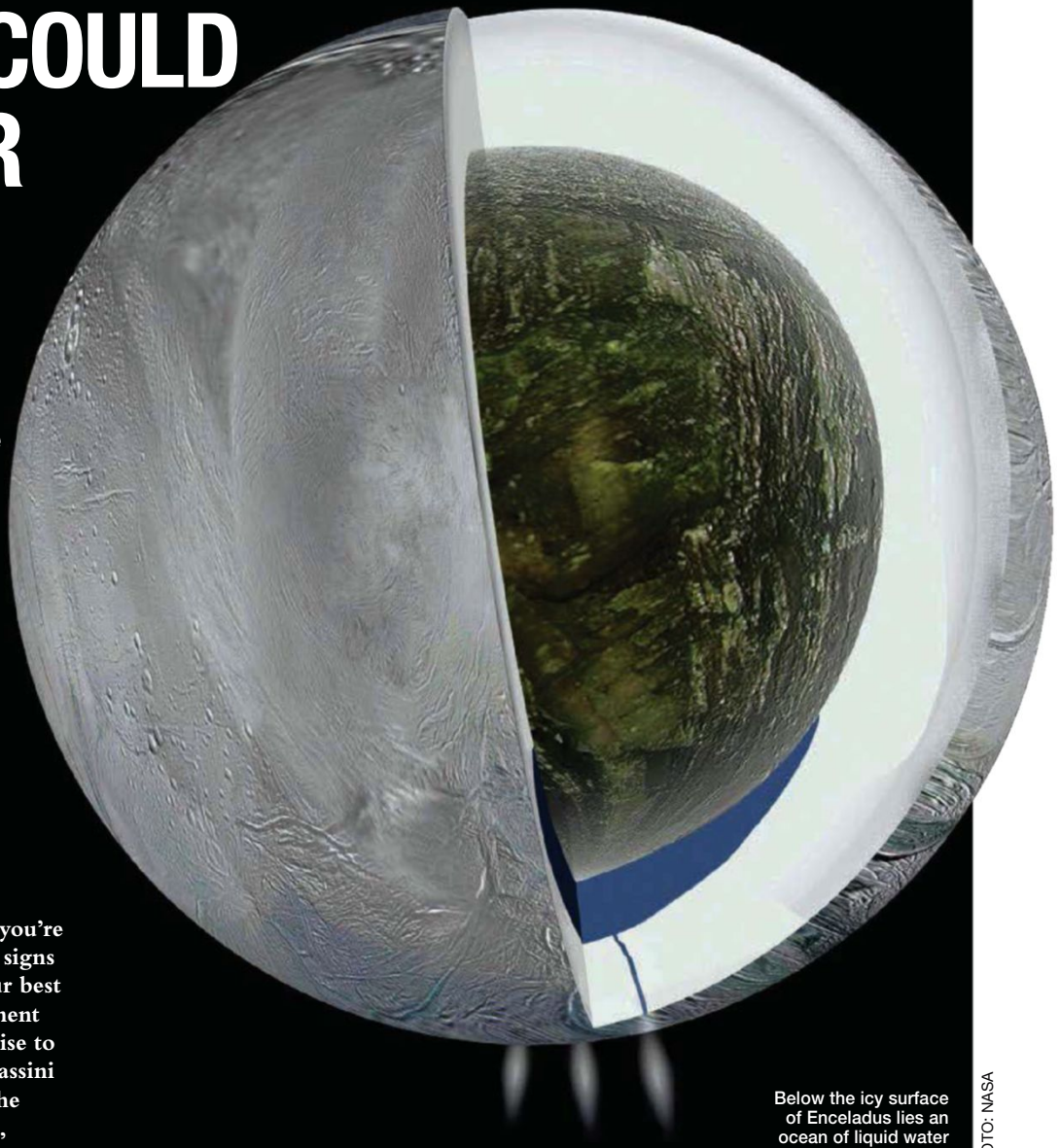
David Shukman on how global warming can affect our food supply


**EXPRESS YOURSELF**

Researchers chart the range of human facial expressions

# ICY MOON OF SATURN COULD HARBOUR LIFE

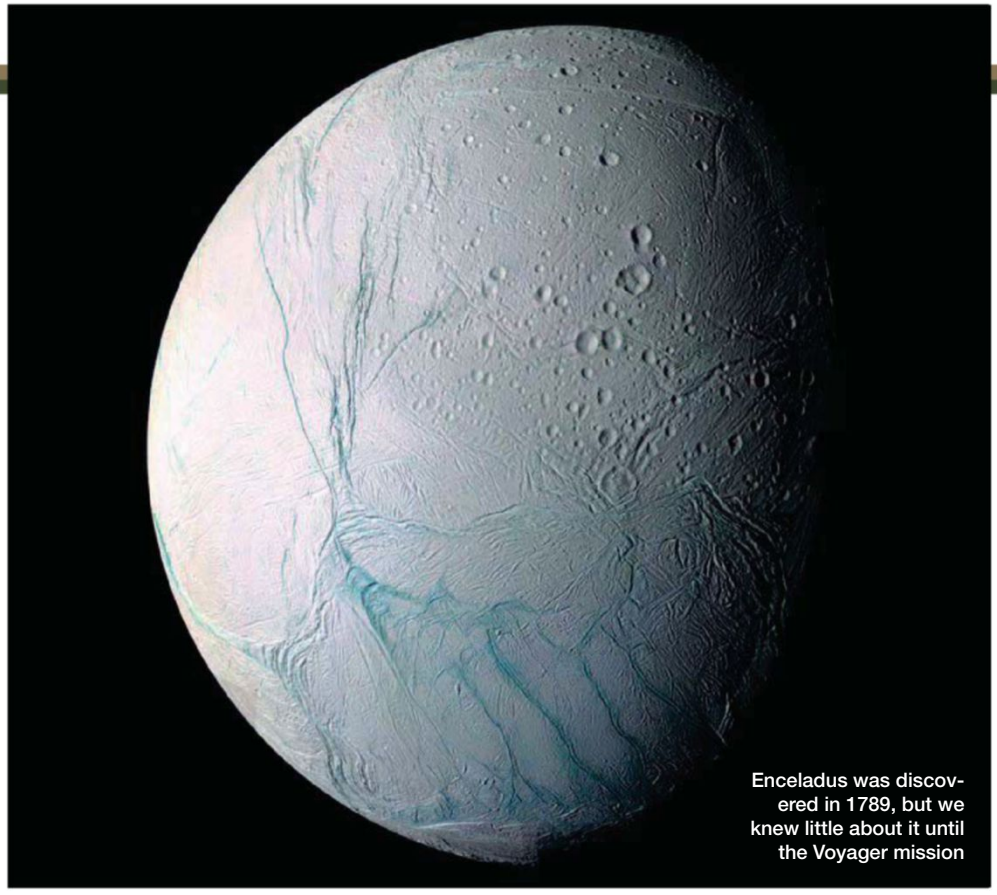
Discovery of subterranean ocean on Enceladus shortens the odds on microbial life existing there



Below the icy surface of Enceladus lies an ocean of liquid water

PHOTO: NASA

Most scientists agree that if you're scanning the Universe for signs of extraterrestrial life, your best bet is to look for water, a key element of the primordial soup that gave rise to life on Earth. And now NASA's Cassini spacecraft has discovered one of the most promising environments yet,



Enceladus was discovered in 1789, but we knew little about it until the Voyager mission

finding evidence that Saturn's icy moon Enceladus harbours a large underground ocean.

Researchers first theorised the existence of a subterranean ocean on Enceladus in 2005, when Cassini discovered plumes of water vapour and ice spewing from vents located close to the moon's south pole. Though Cassini is not able to land on the surface of Enceladus – and though there are no plans to send a spacecraft there in the immediate future – scientists can use measurements of the gravity experienced by Cassini as it flies past the moon to obtain reliable estimates of its internal structure.

"The way we deduce gravity variations is a concept in physics called the Doppler Effect, the same principle used with a speed-measuring radar gun," explains Sami Asmar of NASA's Jet Propulsion Laboratory. "As the spacecraft flies by Enceladus, its velocity is perturbed by an amount that depends on variations in the gravity field that we're trying to measure. We see the change in velocity as a change in radio frequency, received at our ground stations here, all the way across the Solar System."

The measurements made by Cassini during three fly-bys made between April 2010 and May 2012 suggest there is a large body of water about 10km (6 miles) deep, beneath an ice shell about 30 to 40km (19 to 25 miles) thick. Along with the discovery of salt and organic molecules in the vapour plumes emitted from the moon, the findings point towards Enceladus being among the most likely places in our Solar System to host microbial life.

**ANALYSIS**

## Dr Lewis Dartnell

Astrobiologist at the University of Leicester and author of *Life In The Universe: A Beginner's Guide*

"The new cassini findings are very exciting. It's another stepping stone on our way to finding extraterrestrial life.

There are several locations in the Solar System that astrobiologists think are potential habitats. Mars is obviously one of them, and there has also been a lot of interest in Europa, a moon of Jupiter, because there is an underground ocean there. Then about five years ago, out of nowhere, came Enceladus, this tiny little snowball of a moon that has fountains of water gushing out of its surface.

When we analysed those fountains – by flying through them with the Cassini space probe and getting it to hang its tongue out to taste that water – we realised that it was salty, and that there were organic molecules in there as well. The basic requirements for life as we understand it are liquid water, organic molecules to build cells out of, and some kind of energy source, which Enceladus could have as well. So it ticks all the boxes.

We still have Cassini, which is exploring Saturn and Enceladus, and we might discover further things with our measurements from that. But what people are likely to start talking about more and more now is a dedicated Enceladus mission.

We might want to go back in a couple of years' time, perhaps to fly through the fountains of water, collect some of it and then loop back to Earth for scientists to study it."

## TIMELINE

### How our knowledge of Enceladus has evolved over time

**1789**

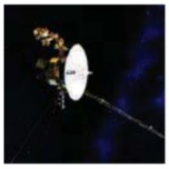
Hanoverian-born British astronomer William Herschel discovers a moon orbiting Saturn. Three days later he discovers another moon, Mimas.

**1847**

Herschel's son John names the moon Enceladus, a character from Greek mythology.

**1980**

Voyager 1 finds Enceladus has a diameter of just 500km and orbits around Saturn's diffuse E Ring, which unlike the other rings is made up of microscopic particles.



**2005**

NASA's Cassini spacecraft flies within 175km of Enceladus and discovers plumes of water vapour issuing from cracks in the moon's frozen surface.

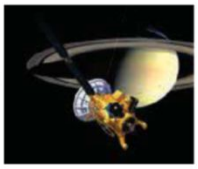


PHOTO: GABRIEL WAKSMAN/UCL/BIRKBECK INSTITUTE, THINKSTOCK X2, PRESS ASSOCIATION

## 1 MINUTE EXPERT
### Nanodot

**What's that? This season's new must-have fabric pattern?**
Way off the mark. Nanodots are tiny nanometre-scale structures that utilise the properties of quantum dots to confine magnetic or electrical fields to incredibly small areas.

**Right. So what are quantum dots?**
They are essentially semiconductor crystals with a size of around 2 to 10 nanometres across; roughly equivalent to around 50 atoms. Due to their small size, quantum dots have properties that lie somewhere between larger semiconductors and individual molecules.

**So what can they be used for?**
They are currently being developed for use in everything from computer displays to storage media. However, Israeli company StoreDot recently demonstrated a battery based on nanodot technology that it claims can charge to full capacity in just 30 seconds. They also say their battery is about five times more powerful than regular batteries and so could be used to make smaller power sources for mobile devices.

**Wow. When can I get one?**
The technology is still in the development stages but StoreDot hopes to release the battery commercially in late 2016.

Neuroscience

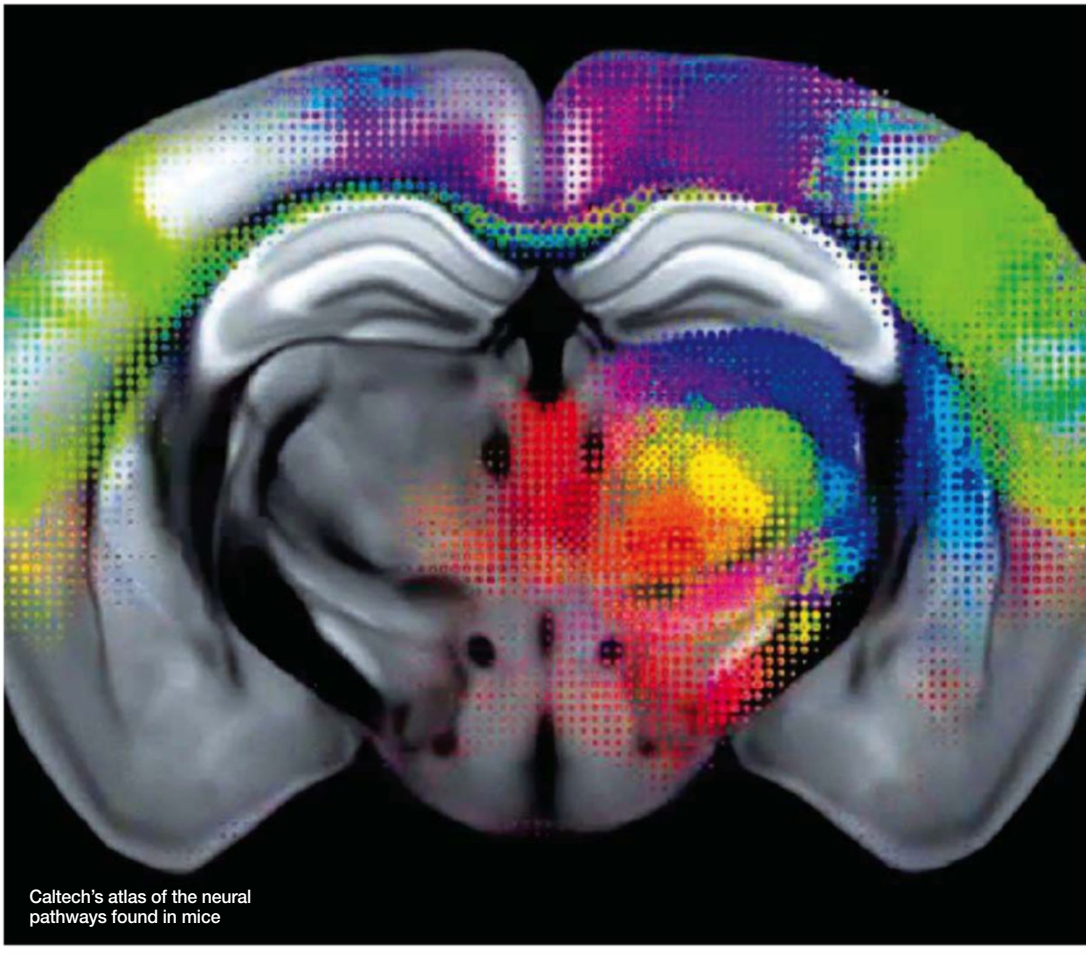
# Mouse brain wiring mapped

Making the London A to Z seem like a simple picture book, researchers at the Allen Institute for Brain Science have pieced together the first ever map of a mammal's neural network.

The Allen Mouse Brain Connectivity Atlas shows the 'connectome', a kind of neural wiring diagram, of the rodent's brain. To achieve this, researchers injected more than 1,700 mice with genetically engineered viruses that could trace and illuminate individual neurones. They then produced a series of images of the organs at resolutions 50 times smaller than the diameter of a human hair and assembled the data. The resulting 3D map contains more than 1.8 petabytes of data, equivalent to 24 years' worth of HD video.

"The atlas provides an initial road-map of the brain, at the level of interstate highways and the major cities that they link," explains Caltech's David Anderson. "Smaller road networks and their intersections with the interstates will be the next step, followed by maps of local streets in different municipalities. This information will provide a framework for what we ultimately want to understand: 'traffic patterns' of information flow in the brain during various activities such as decision-making, mapping of the physical environment, learning and remembering, and other cognitive or emotional processes."

The mouse brain atlas brings us a step closer to fully understanding the complexities of the mammalian brain. Researchers say that the next step will be to figure out more accurately how the brain's circuitry functions.



Caltech's atlas of the neural pathways found in mice

PHOTO: ALLEN MOUSE BRAIN CONNECTIVITY ATLAS

# DAVID SHUKMAN

## The science that matters

# How global warming will affect our food supply

Droughts in the Amazon basin can have far-reaching consequences

Most of us never even think about the vulnerability of the food industry until something goes wrong. Extreme weather conditions in distant lands, such as a heatwave in Texas, can hike prices for a staple crop like maize dramatically. It's why research into how climate change could affect future harvests is increasingly relevant.

Some years ago, in the sweltering heat of the Amazon rainforest, I saw one of the most controversial elements of the international food network first-hand. Giant ocean-going freighters were steaming upriver to collect cargoes of soya. Grown on land where rainforest used to stand, the soya is shipped across the Atlantic to become an ingredient in chicken feed. The year before, a drought had damaged the crop so prices for soya had shot up, and that made British-reared chicken more expensive too. Later, in Belfast docks – one of the receiving ends of the trade – I watched a dusty cargo of Brazilian soya coming ashore and learned how droughts in the Amazon could do more than cripple the harvest. A lack of rainfall can also mean the river becomes too shallow for the ships to carry full loads. When they have to sail half-full, the transport costs rise, adding yet more to the price of the soya and everything that relies on it.

Looking ahead, basic biology might suggest a rising level of atmospheric CO2 would be good for plants – growers pump the stuff into their greenhouses after all. And indeed, a few crops in some regions may do better in coming years – and the most adaptable farmers will quickly spot new opportunities. But most plants will fail to thrive when temperatures become too fierce and water supplies run too low. According to the UN's Intergovernmental Panel on Climate Change, further warming is likely to reduce yields overall, with the greatest risks in the second half of the century.

International trade has made food cheaper but also made supplies more volatile – which means that climate change is about much more than warming. Just a thought for the next time you look down at a plate of chicken.

**DAVID SHUKMAN** is the BBC's Science Editor. @davidshukmanbbc

# THEY DID WHAT?!

## Beer made from fossilised yeast

**What did they do?**

A beer maker in Virginia, USA, has created a drink from 35 million-year-old yeast found on a whale fossil. The new brew, which has been named Bone Dusters Paleo Ale, is said to taste 'Belgian'.

**How did they do that?**

The brewers originally wanted to collect yeast, the microorganism needed for brewing, from inside a piece of amber, à la dino resurrection movie Jurassic Park. After finding this method too difficult, they found a sample on a prehistoric fossil instead, discovering a new subspecies of yeast that they used to create a tasty citrus-flavoured ale.

**Why did they do it?**

The aim was to get the public interested in palaeontology and science – as well as making a refreshing pint, of course.

PHOTO: GETTY ILLUSTRATOR: ADAM HOWLING

# PATENTLY OBVIOUS

## Inventions and discoveries that will change the world with James Lloyd

### All in the blink of an eye

Google's smart glasses haven't even hit the streets yet, but the tech giant is already working on smart contact lenses.

A recent patent application reveals how the intelligent lenses will enable you to control gadgets with a wink of the eye. Sensors placed around the edge of the lens will detect when you blink – by monitoring, for example, the dip in light when your eyelid is closed. It'll also measure your blinking speed so it can tell the difference between your purposeful winks and your involuntary ones.

The smart lens will then communicate wirelessly with any gadget it's linked up to. You could use it to turn the page of an e-book, take photos, turn lights off or scroll through music tracks. It'll even be able to recognise different patterns of blinking, letting you communicate with your gizmos in a kind of ocular Morse code.

**Patent application: WO2014043614**

### The robotic octopus

Following on from BigDog, Cheetah and RoboRoach, the octopus is the latest creature to inspire the world's roboticists. A team in Italy is hoping to patent a robot with soft arms that extend radially from its body like those of the sea-going cephalopod. Its flexibility means that it'll be able to crawl over obstacles with ease, while its multiple limbs will allow it to grip objects and travel at the same time. Get ready to welcome our new tentacled overlords.

**Patent application: US 20140083230**

### If the shoe fits…

Feeling too lazy to tie up your shoelaces? You may be interested in Nike's motorised shoes. Looking like something out of Back To The Future, the space-age sneakers will sport a battery-powered lacing system. The patent describes how the shoes could work wirelessly with a bracelet or iPhone, so you can tighten or loosen them without bending down. They could even respond to your voice, as long as you don't mind being seen talking to your feet.

**Patent application: US 20140070042**

## WHO'S IN THE NEWS?

### Michael Smith

A postgraduate student at New York's Cornell University

**What did he do?**

Had bees sting his penis and scrotum along with 23 other areas of his body. Deliberately. He then rated the resulting pain on a scale of 0 to 10.

**Why did he do that?**

As a researcher of bee behaviour, stings are presumably an everyday occurrence for Smith. However, when a particularly intrepid bee found its way into his shorts and stung him on the scrotum, he was surprised that it wasn't as painful as he expected. This made him wonder how the pain of stings varies across the body.

**What did he find?**

Surprisingly, the most painful area to be hit with the excruciating venom was the nostril, receiving an eye-watering 9 out of 10 on the pain scale. The scrotum and the penis came in at 7.3 and 7 respectively, which is still very painful. The least painful regions were the skull, toe and upper arm, each scoring just 2.3. Still, we advise that you don't try this at home.

Medicine

# Dutch woman gets a 3D-printed skull

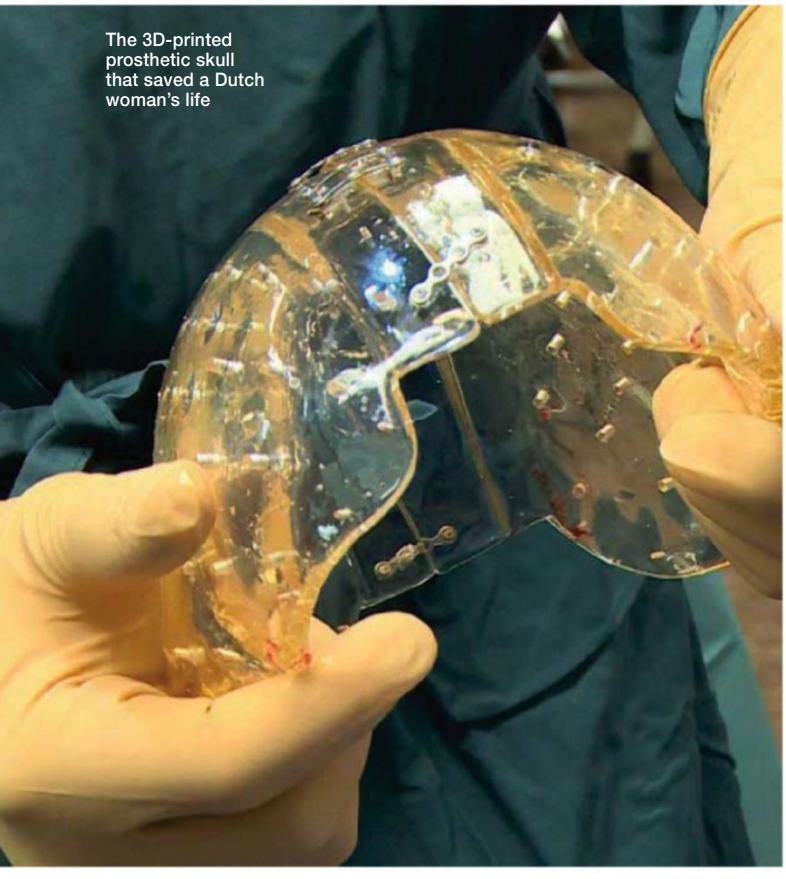
Dutch surgeons have replaced a large section of a woman's skull with a 3D-printed replacement, saving her life in what is being hailed as the first successful operation of its kind.

The 22-year-old patient suffered from a rare disorder that caused her skull to grow extra bone. This applied extra pressure to her brain, giving the woman severe headaches and a gradual loss in vision.

If left untreated, the condition would eventually have killed her. But in a 23-hour operation led by neurosurgeon Dr Bon Verweij at the University Medical Center Utrecht, the top of the patient's skull was removed and replaced with a custom-made plastic copy that fitted neatly with the rest of her skull.

The operation was a resounding success. "The patient has fully regained her vision," said Verweij. "She has no more complaints, she has gone back to work and there are almost no traces that she had any surgery at all."

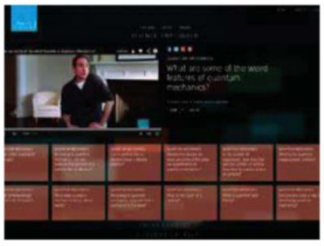
The team now hopes that the technique will help to reconstruct skulls that have been severely damaged in accidents or by brain tumours.



The 3D-printed prosthetic skull that saved a Dutch woman's life

# CLICK HERE

## New websites, blogs and podcasts



### *World Science U*

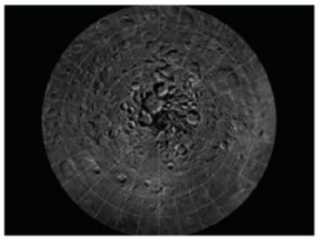
*www.worldscienceu.com*

This new physics and cosmology site from Brian Greene has something for everyone. Dip into short answers to specific questions like 'Is anti-gravity possible?', take two to three work courses that come with no homework, or, if you really want to dive deep into a subject, take a longer university course on relativity or quantum mechanics (or both).

### EPI

*http://tinyurl.com/mx2l3ok*

By typing key words from the 2014 Environmental Performance Index survey into Google, researchers have been able to make this map of how our perception of the global environment differs from what it actually is. For instance, people searched for 'why Canada is one of the worst abusers of the environment', when in fact it came 24th out of 176 countries.



### LROC

*http://lroc.sese.asu.edu/gigapan*

The Moon is our closest astronomical neighbour, yet most people will never get to see it up close. A new online tool from the Lunar Reconnaissance Orbiter fixes this by letting you pan around the Moon to your heart's content, looking at detailed images the orbiter's camera took over four years in orbit around the satellite.

### TALK NERDY TO ME

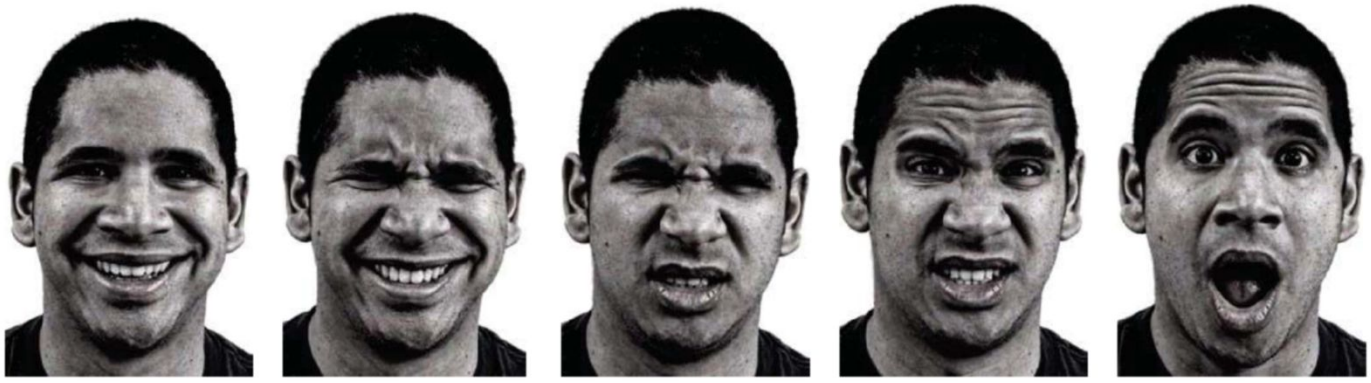
*carasantamaria.com/podcast/*

Cara Santa Maria talks nerdy to a variety of scientists and science writers. Covering subjects as diverse as the Universe and the science of self, these hour-long podcasts feature one guest each and really go in depth on the topics they cover, allowing plenty of room for the nuance that is missing in a lot of science coverage. One to save for a long car journey.

## GRAPHIC SCIENCE

Seeing research differently

# EMOTIONS ARE WRITTEN ALL OVER OUR FACES



Happy | Happily disgusted | Disgusted | Disgustedly surprised | Surprised

Sadly surprised | Sad | Sadly angry | Angry | Fearfully angry

How are you feeling right now? Happily disgusted, perhaps? How about sadly angry? Researchers at Ohio State University have used computer modelling to identify 21 distinct human facial expressions, including those corresponding to the seemingly contradictory feelings mentioned above. They hope the work will be useful in helping to map emotional responses in the brain and potentially aid the diagnosis and treatment of conditions such as post-traumatic stress disorder (PTSD) and autism.

PHOTO: OHIO STATE UNIVERSITY, FLORIAN MUJRES

ZOOLOGY

# Swat team

Fruit flies can be pretty tricky to swat. Now, a team at the University of Washington has figured out why: they employ evasive manoeuvres reminiscent of those carried out by fighter pilots. Researchers at the University of Washington exposed flies to images of approaching predators and captured their responses using high-speed video cameras running at 7,500 frames a second.

"Although they have been described as swimming through the air, tiny flies actually roll their bodies just like aircraft in a banked turn to manoeuvre away from threats," said study lead Michael Dickinson. "We discovered that fruit flies alter course in less than one 1/100th of a second, 50 times faster than we blink our eyes, which is faster than we ever imagined."

During the acrobatic manoeuvres the flies can roll more than 90 degrees, and at times almost fly upside down. Dickinson now wants to figure out how the flies are capable of such complex movements. "A fly with a brain the size of a salt grain has a behavioural repertoire nearly as complex as a much larger animal such as a mouse," he said. "That's an interesting problem from an engineering perspective."

Fruit flies in training for this year's International Airshow

Scientists at Duke University have invented a practical sonar cloaking device

Engineering

# Hear no evil

It's every supervillain's dream: a device for hiding a secret underwater lair from the prying ears of military sonar. Well, that dubious wish may soon become a reality. Engineers at Duke University have created an acoustic cloak that can effectively reroute sound waves around any object to create the sonic impression that there is nothing there. The resulting device is a complex pyramid-like structure constructed of perforated plastic plates.

"The structure that we built might look really simple. I promise you it's a lot more difficult than it looks," says Steven Cummer, professor of electrical and computer engineering at Duke. "We put a lot of energy into calculating how sound waves would interact with it."

To give the illusion that it isn't there, the cloak alters the sound waves' trajectories to match what they would look like had they reflected off a flat surface.

The technology could be used in sonar avoidance or in controlling the acoustics in concert halls, Cummer says.

PHOTO: DUKE UNIVERSITY, ZACK VEILLEUX/THE ROCKERFELLER UNIVERSITY, PRESS ASSOCIATION

Biology

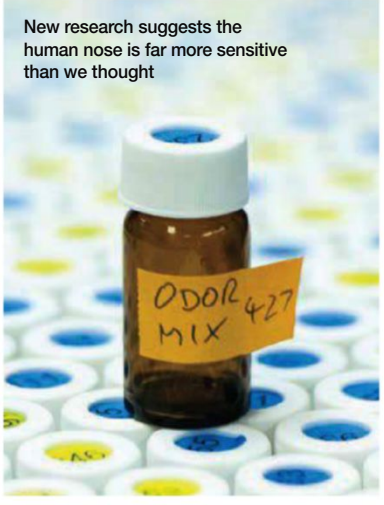
# You smell good!

As anyone who has caught a whiff of a cheesemonger's apron knows, the human sense of smell can be pretty sensitive. In fact, according to a study carried out at The Rockefeller University, the humble human schnoz is able to detect more than 1 trillion odour mixes. That figure far outstrips the generally accepted number of just 10,000.

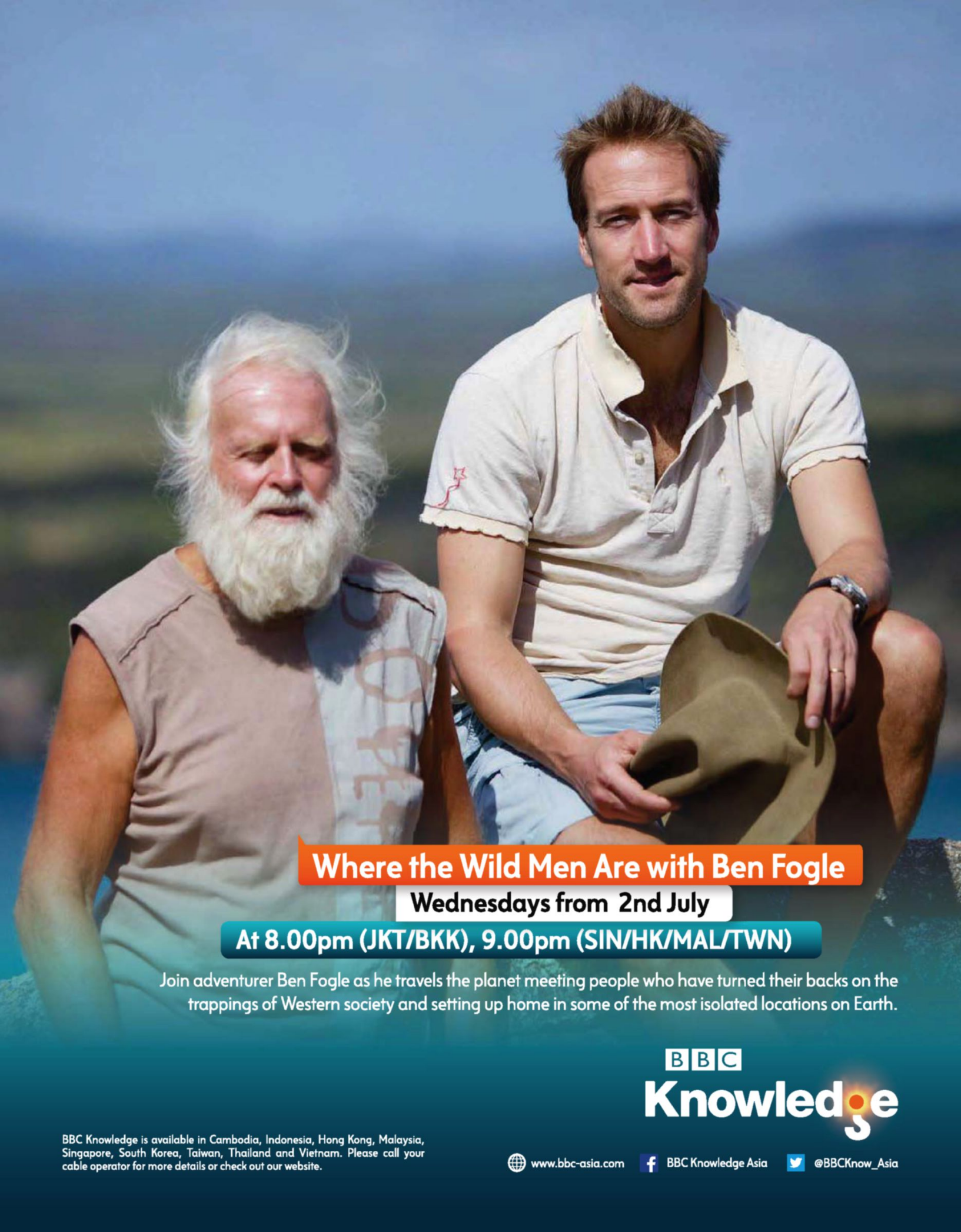
"The message here is that we have more sensitivity in our sense of smell than we give ourselves credit for. We just don't pay attention to it and don't use it in everyday life," says Andreas Keller, who led the research project.

Scents are composed of complex mixes of molecules, making them incredibly difficult to study. For example, the characteristic smell of a rose has 275 components. To overcome this, Keller compiled a shortlist of 128 odour molecules that are responsible for powerful scents such as orange, anise and spearmint, and mixed these molecules in a variety of proportions.

He then presented volunteers with three vials, two of which containing identical mixes, and asked them to pick the odd one out. By analysing the data, the researchers were able to calculate the total number of distinguishable mixtures.




New research suggests the human nose is far more sensitive than we thought


Where the Wild Men Are with Ben Fogle
Wednesdays from 2nd July
At 8.00pm (JKT/BKK), 9.00pm (SIN/HK/MAL/TWN)
Join adventurer Ben Fogle as he travels the planet meeting people who have turned their backs on the trappings of Western society and setting up home in some of the most isolated locations on Earth.
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# Comment & Analysis

## The curious tale of the cyclist, the scorpion and a beam of ultraviolet light

You may think that cyclists and scorpions have nothing in common. But you'd be wrong. Both have a bit more to their appearance than meets the eye. Last week, I was peddling to work on a dull, grey day and I stopped at traffic lights behind about 20 other cyclists. Between them, they were wearing a huge variety of colours, but five or six of them popped out of the scene almost as if they had spotlights on them. I found myself wondering why yellow high-visibility clothing is so much brighter than everything else. After all, it's just a colour, isn't it?

Our world is flooded with oodles of light, at least during the day. But what we see is only what's left over after its journey has extracted a toll. As light travels through the atmosphere and bounces off the objects around us, the environment is chipping away at it. Everything that the light passes through or reflects off will absorb and scatter some wavelengths. My notebook is red because its cover absorbs every other colour, so red is all that's left when that light reaches me. The character of the light that we see is just what's left over after all those subtractions. In theory, there's a fingerprint there from every part of its journey since it left the Sun.

So, back to the high-visibility jackets. What was bothering me is that they were so much brighter than everything else, even though that light had been through a similar series of subtractions to everything else around them. But the high visibility dye has an extremely clever trick up its sleeve. It is taking advantage of something that I couldn't see in that scene: ultraviolet light or UV.

The lenses of our eyes protect us from it, but quite a lot of UV passes through clouds, so even on a dull day there's quite a bit of it about. The dye molecules absorb high-energy UV light and emit lower-energy visible light. They are taking the light we can't see and turning it into light that we can see. The reason high-visibility clothing looks like it's glowing on a dull day is that it really is – it has an extra source of energy. There is still no such thing as a free lunch, but the cost comes in a region of the spectrum that we don't care about. This is why high-visibility jackets are no good in the dark – there's no natural UV light around to give them that extra glow. It's not just jackets either – these dyes are used in laundry brighteners and highlighter pens and all sorts of other things. If you shine UV light on them in a dark room, you'll see the glow. This is fluorescence.

ILLUSTRATOR: CIARA PHELAN

**"Cyclists are letting me detect UV light. If their jackets are glowing, UV must be there, even though I can't see it"**

I love this idea because it means that the cyclists are letting me detect UV light. If their jackets are glowing, UV must be there, even though I can't see it. A bit further down the road, I remembered that this happens in the natural world too. Ask the experts how to find a scorpion, and they'll tell you to go out in the desert at night with a UV light. Scorpions glow blue-green in UV, because they have fluorescent molecules built in to their exoskeleton. No-one really knows why, but it's thought that it might help them find dark places to hide, especially around twilight when the proportion of UV light is higher. If that's the case, their whole exoskeleton is a UV detector, shifting invisible light down into the colour range that the scorpion can see. We tend to assume that we can see everything that there is, but the world is richer than that.

Next time I see a high-visibility jacket shine out of a dull scene, I'll remember it's a sneak peek into the world of invisible colours.

**DR HELEN CZERSKI is a physicist, oceanographer and BBC science presenter who appears regularly on *Dara O Briain's Science Club***

# HOW SCIENCE WILL HELP YOU LIVE TO 100 AND BEYOND...

We're on the cusp of a medical revolution. **Lilian Anekwe** reveals how studying the human genome will radically extend your lifespan

Scan this QR Code for the audio reader

ILLUSTRATOR: JUSTIN METZ

What if you could live past 100 years of age? Would you want to? It's a question we might all need to start thinking about. In recent months some of the world's highest-profile pioneers have announced they are turning their attention to finding the genes that could make us live forever. Their ambition: to hunt down the illnesses that affect us in old age.

The forerunner in this race to help us live longer has to be Craig Venter: the geneticist, entrepreneur and philanthropist behind the Human Genome Project, whose own genetic information was among the first ever published in 2011. In March this year, he announced his latest project would use $70 million of venture capital to set up a new company called Human Longevity Inc (HLI).

But Venter isn't alone in his ambitions. In September 2013, Google CEO Larry Page announced he had appointed Art Levinson, chairman of Apple and biotechnology company Genentech, as CEO of Google Calico (California Life Company). Calico has the straightforwardly ambitious remit of improving human health and well-being, and solving the challenge of ageing and associated diseases.

## A giant undertaking

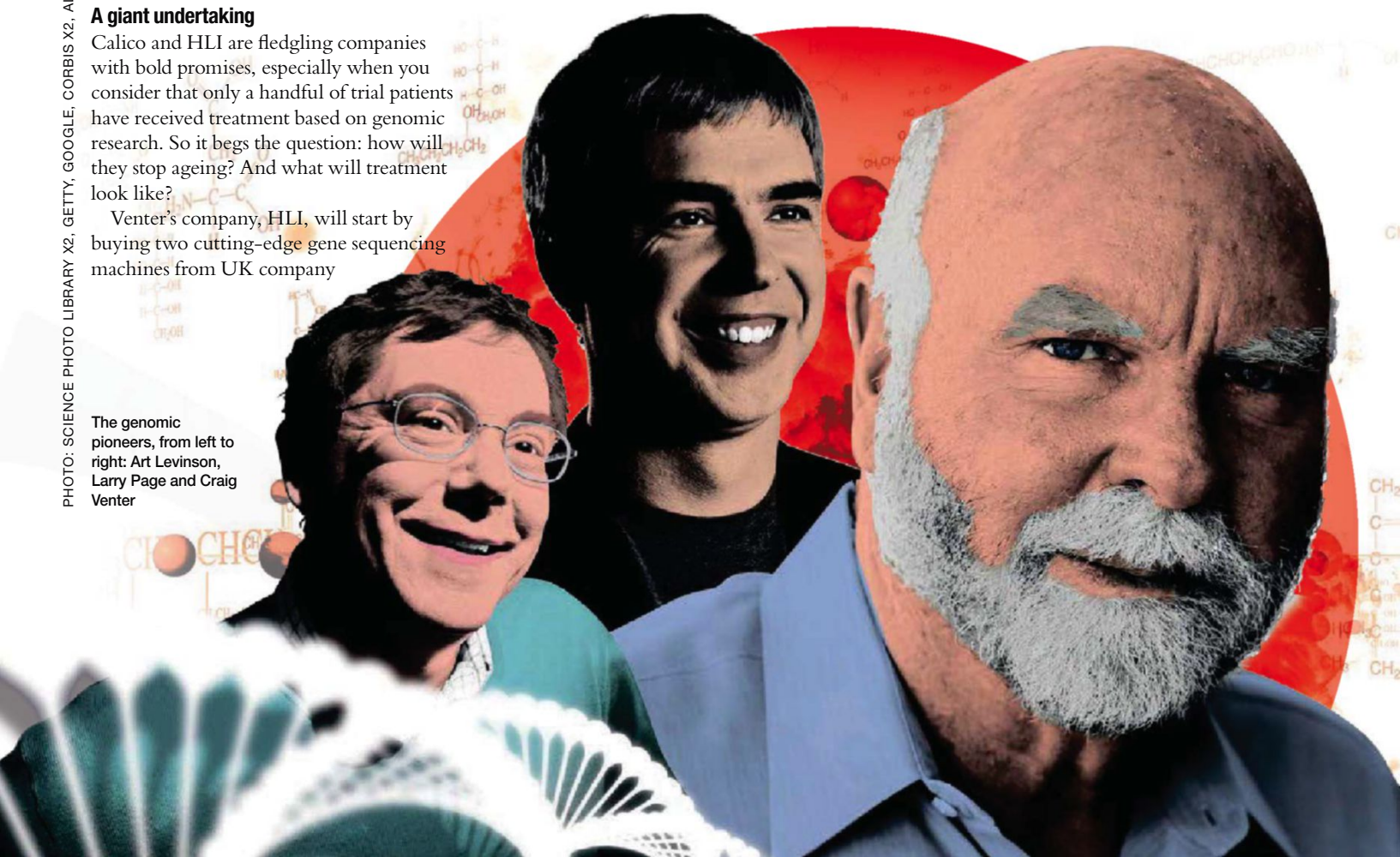
Calico and HLI are fledgling companies with bold promises, especially when you consider that only a handful of trial patients have received treatment based on genomic research. So it begs the question: how will they stop ageing? And what will treatment look like?

Venter's company, HLI, will start by buying two cutting-edge gene sequencing machines from UK company Illumina with its investment money, and sequence the genomes of 40,000 people, eventually ramping up to 100,000 people a year. At the same time HLI hopes to catalogue the bacteria that live in and on the human body in an ecosystem known as the microbiome, and sequence the metabolome – the genetic information about the biochemicals in the body.

It's an enormous undertaking but Craig Venter is confident this big genetic data approach will answer the biggest questions about human life, and death, ushering in a new age of medicine. "We're likely to gain a better understanding of human lifespan with this approach," he says. "But if all we could learn about was the sequence of the genome I would not waste my time or the money. The potential is to truly understand our genetic propensity for health and disease. We think we can answer for the first time in history the question everybody asks: what's nature and what's nurture?"

"It isn't a coincidence that these ventures have launched within months of each other," says Dr Scott Lippman, director of the Moores Cancer Center at the University of California, San Diego – where every


Science could help you celebrate such a landmark



The genomic pioneers, from left to right: Art Levinson, Larry Page and Craig Venter

PHOTO: SCIENCE PHOTO LIBRARY X2, GETTY, GOOGLE, CORBIS X2, ALAMY, THINKSTOCK, NEW YORK GENOME CENTER

# 5 THINGS YOU CAN DO TO START LIVING TO 100 NOW

Masa Narita of Osaka, Japan turned 100 in February; keeping her social life going has helped make her a centenarian

The family of 101-year-old Tomiko Kadonaga, a Canadian, say that the secret to her long life has been her sense of positivity

## BOOST YOUR SOCIAL NETWORK

This doesn't necessarily mean signing up for a new Facebook account, but having a strong social network of friends and family around you to provide support during stressful situations in life is vital to make it to the big one hundred. One study by researchers at Brigham Young university found that people with a solid group of friends are 50 per cent more likely to survive at any given time than those without one.

## STAY POSITIVE

Your personality could be important in ageing. Studies of the children of centenarians found they are more extroverted and less neurotic than others. Similarly, a study in the journal *JAMA Psychiatry* found that people who feel they have a sense of purpose in life tend to live longer. And people who feel that ageing gives them more time to do meaningful things, like spending time with family or helping others, lived longer, according to research by the Longevity Project at Stanford University.

Now 103, Fauja Singh became the first ever 100-year-old to finish a marathon. The event was the Toronto Waterfront Marathon in 2011

Dorothy Newell celebrates her 100th birthday last February in Detroit; eat a balanced diet and you could make it to this ripe old age

Seven hours' kip a night is the optimum amount to live longer - maybe think about resetting that alarm clock

## GET MOVING

We all like to laze around a bit, but researchers are saying that inactivity is drastically reducing our lifespan. Being sedentary has been linked with diabetes, obesity, heart disease and cancer - all big killers of people in their old age. A study in 2011 estimated that our lives are about 22 minutes shorter for every hour we spend sitting watching television after the age of 25. So why not get off the couch and try reading the rest of this article standing up?

## EAT A BALANCED DIET

Studies of rats fed a calorie-restricted diet have found this can double their lifespan. But this hasn't been conclusively proven in humans. In fact, studies of Ashkenazi Jewish centenarians in the US found they didn't stick to any particular diet and were just as likely to be overweight as their shorter-living peers. In other regions where centenarians are common (Okinawa, Japan, and Sardinia, Italy) the diet includes little, if any, processed food.

## ...AND SLEEP

Around seven hours a night could be the best amount for a longer life. Researchers at the Scripps Clinic Sleep Center in California found a U-shaped relationship between the average number of hours of nightly sleep and death rates in a study of more than a million American adults. People who slept between 6.5 and 7.5 hours a night lived the longest, and people who slept for more than eight or less than 6.5 hours a night didn't live quite as long.

## "We can answer for the first time in history: what's nature and what's nurture?"

Craig Venter, biologist and entrepreneur, co-founder of Human Longevity Inc

Dr Scott Lippman thinks that technology has made it possible to usher in an era of genomic medicine

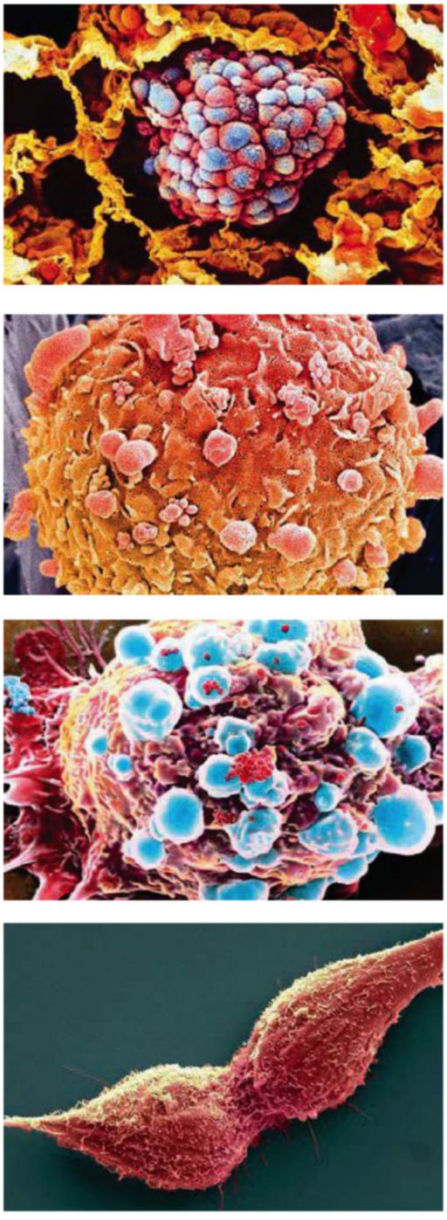
cancer patient who consents will have their genomes and tumours sequenced by HLI.

Since the first human genomes were sequenced in 2011, the field has progressed at a rapid pace and now cancer researchers are at the cusp of "the next frontier in science", explains Lippman. "Right now we are in a period that is going to be transformational for cancer, in a similar way that the '90s were for the internet. We understand the genome, and the technology means sequencing on this scale can be done quickly and more cheaply than before. What used to take us 15 to 20 years we can now do in a year or two. The cancer field is moving very quickly and this is just the tip of the iceberg."

According to the World Health Organisation, cancer was the third highest global killer in 2011, causing one in seven of all deaths worldwide, and for the most part cancer is a disease associated with old age. HLI plans to use the genome data it generates from sequencing to identify and analyse the genes involved in cancer and find potential new treatments.

The sequencing of genes will be just one battlefront in the war against ageing. Dr

The complex array of channels of a genome sequencing machine, which can decode human DNA



Cancer is an age-related disease and comes in many forms – it's hoped that researching the genetics of ageing will help tackle various types of cancer. From top to bottom: lung, skin, breast and prostate cancer cells

## SHOULD WE BE TRYING TO LIVE TO 100?

We asked two experts to argue the ethical case for longevity

With a rising population putting pressure on resources, is it right for us to live longer?

For many diseases survival rates have already increased dramatically, which Dr João Pedro de Magalhães, from the integrative genomics of ageing group at the University of Liverpool describes as "one of the greatest achievements of technology".

"I don't think leaving people to die just to control overpopulation is ethical. If people are healthy they will choose to live as long as they can, that's human nature," says de Magalhães. "There may be a sweet spot, an optimum lifespan where we can enjoy longevity, but not cause societal problems. It wouldn't be without issues in some countries with overpopulation and a depletion of resources. But it's not true that the population will necessarily explode. In terms of population growth the number one factor isn't how long people live, it's how many babies they have. The countries with the fastest population growth are not the same countries where people live a long time."

Stopping ageing isn't enough on its own, says Dr Alex Zhavoronkov, director of the UK-based think tank the Biogerontology Research Foundation and author of The Ageless Generation: How Advances In Biomedicine Will Transform The Global Economy. "The only way to ensure we don't go bankrupt is to increase people's productive longevity," he says. "We don't have an option or an alternative. If we don't act quickly to extend healthy productive longevity in the next 20 years there will be a major economic collapse - much worse than global warming or the depletion of fossil fuels."

PHOTO: GETTY X3, ALAMY X2, SCIENCE PHOTO LIBRARY X3, SUPERSTOCK

PHOTO: THINKSTOCK, SCIENCE PHOTO LIBRARY, DAVID AHNTHOLZ, CORBIS

# WHAT WILL THE NEW AGE OF MEDICINE LOOK LIKE?

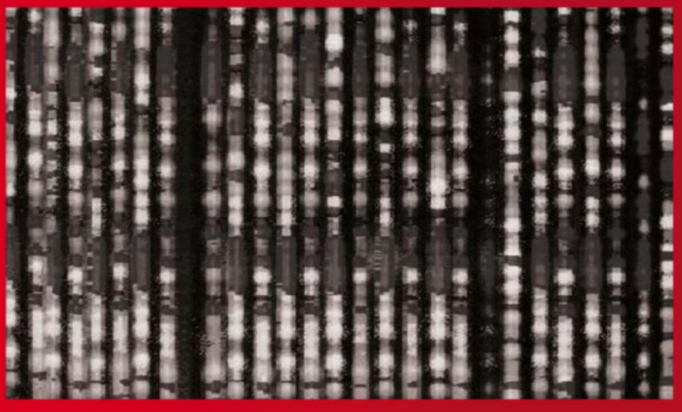
## The amazing therapies on the horizon that will help you live longer

### STEM CELL THERAPIES

As we age our stem cells are depleted and degraded. Sequencing data could be used in the emerging field of regenerative medicine. This involves using stem cells to repair aged tissues, as well as repairing damage to our organs caused by degenerative diseases or physical damage to our bodies as we age.

### PERSONALISED MEDICINE

Genomic data could tell us who will respond to a drug and why certain drugs work better for some people than others. It could allow doctors to choose the most effective drugs for patients with the least side effects.



### PREVENTATIVE MEDICINE

If you could find out how long you have left, would you want to know? You could discover what your genome (human DNA sequence, pictured) says about your risk of cancer and have an optimum longevity package and customised preventative advice to help you make a century.

### FAECAL TRANSPLANTS

The bacteria in our gut (pictured) changes with age. There's a theory, however unappealing you might find it, that suggests we can use a microbiome analysis to identify someone with 'young' gut bacteria, and transplant poo - which contains their gut bacteria - to rejuvenate the microbiome of an older person.


### BIOINFORMATICS

Researchers at IBM and the New York Genome Center (pictured) are designing computer programs that cancer doctors can use to upload an analysis of your genes and mutations. The software would then study your genetic code and provide a shortlist of relevant drug options that will work best for you.

Razelle Kurzrock, director of personalised cancer therapy at Moores Cancer Center, sees other ways that HLI's genome catalogue could change medicine. "At the moment we are lumping people with different cancers together. That has been helpful to a limited extent, but it's been hard to make great leaps using these techniques," he says. "That's because 100 lung cancer patients may all have different abnormalities that drive the growth of their cancer. Only a small fraction will respond to a treatment.

"In the past we have not been able to differentiate which patients will respond to treatment or which will have side effects. Genomics should allow us to personalise therapy according to people's genetic profile – this is the basis of personalised therapy. It's my belief that personalised therapy will spread to influence all of medicine. The potential is enormous."

The hope is that what HLI learns about cancer can be applied to diabetes and obesity, heart and liver diseases, and dementia. But finding treatments for these illnesses may not be enough to increase human longevity. After all, it's estimated that even if we found a cure for cancer this would only increase the average human lifespan by a few years – before people die of a different disease.

This is why, according to Craig Venter, the goal of solving one illness – even one which is as big a threat to human health as cancer – is not HLI's ultimate aim. "While we're all going to die of something, your age is your number one risk factor for every disease," says Venter. "In the last few decades the average human lifespan has increased. Fewer people are dying from cancer and heart diseases, but more are living longer with illnesses like dementia that impact quality of life. I wouldn't necessarily call that a healthy lifespan. So the goal is not just to extend lifespan – it's to extend the healthy human lifespan."

### Faulty genes

The fundamental mechanisms controlling human ageing are complex. What we know about the genetics of ageing comes from studies of families, twins and centenarians – people who live beyond 100 years. Longevity tends to cluster within families, and parents and siblings of centenarians have a greater likelihood of living to an advanced age than other people.

From studying these families and searching the genome for small genetic variations that occur more frequently in people with a particular disease, researchers have identified targets like apolipoprotein E, a protein involved in lipid metabolism. A genetic variant in the apolipoprotein E gene (ApoE E4) is the major identified risk factor for late onset Alzheimer's disease. By manipulating these kinds of genes biologists have been able to extend the lifespans of mice by as much as 50 per cent. These genetically modified mice live longer, degenerate slower and develop diseases later.

**"People smoke heavily and still make it to 100. Is this luck? I very much doubt it"**

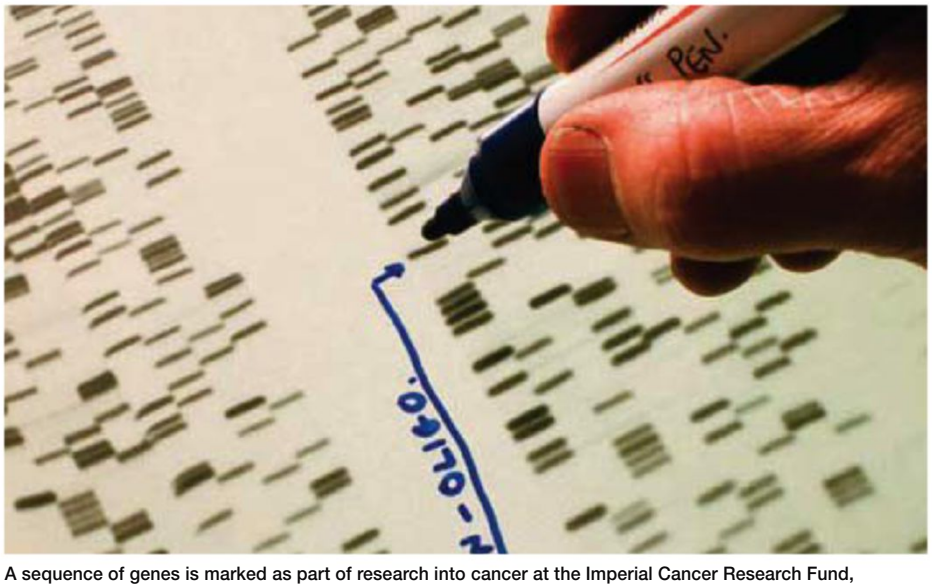
Dr Razelle Kurzrock, director of personalised cancer therapy at Moores Cancer Center

We still don't know if genes identified by the HLI sequencing could be manipulated in humans, but Dr João Pedro de Magalhães, from the integrative genomics of ageing group at the University of Liverpool, says the HLI data will provide a good place to start finding out. "In mice we can retard all aspects of ageing – molecular, cell, longevity and disease – by genetic manipulation. We don't know for a fact that it's possible in humans but in my mind there's no reason to think it's not. Sequencing is the place to start. Genomics has huge potential for ageing. It's an ideal process for large-scale analysis like Human Longevity Inc is proposing."

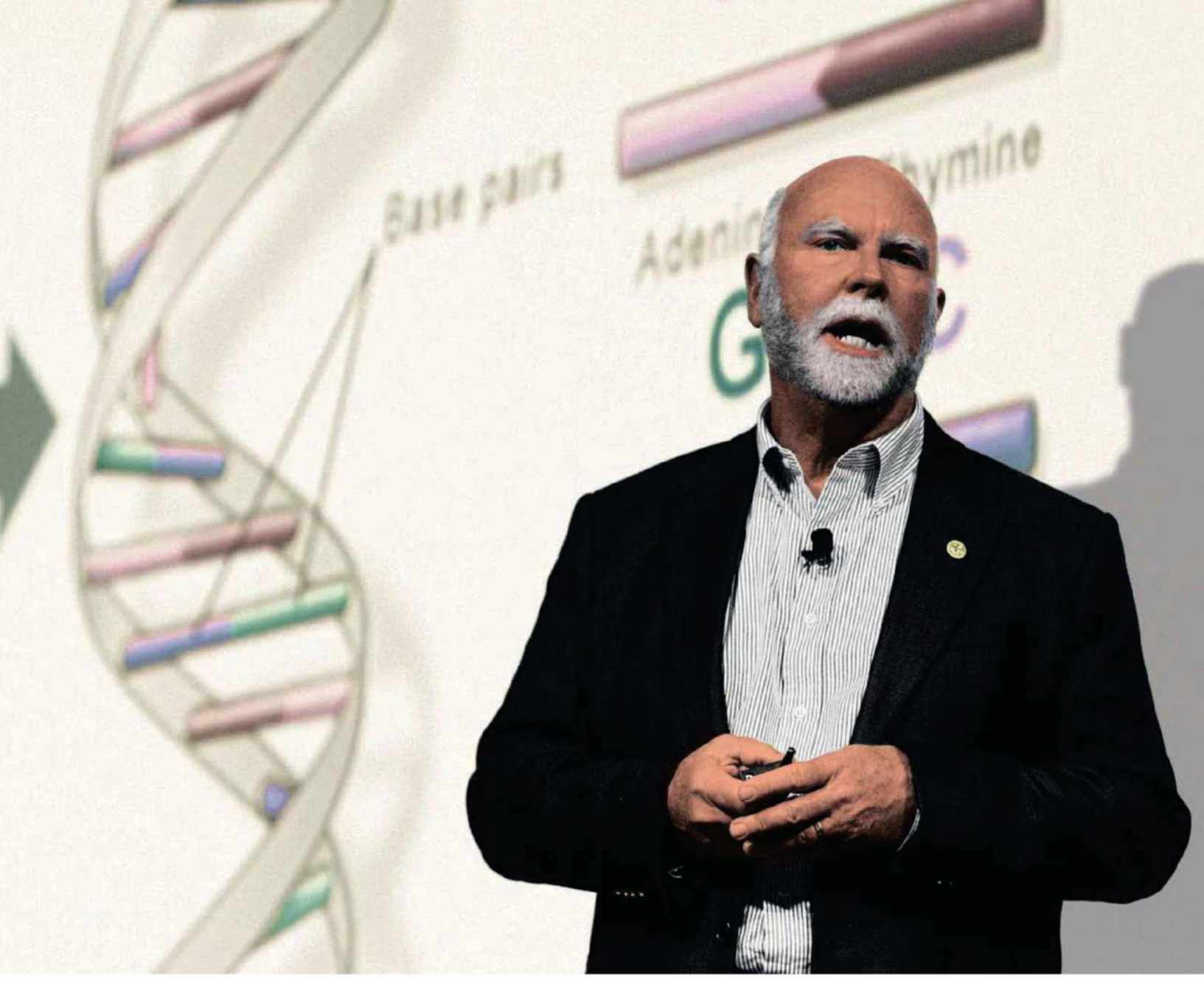
Dr Kurzrock believes our genes plays an important role in determining how long we'll live

### A big data project

It takes a lot of vision to see how the building blocks of our genes, bacteria and metabolites (sequences of four DNA elements tens of thousands of lines long) could control something as complex as ageing. So the sheer scale of the HLI project may make it easier to find target genes, says Dr Leonard Guarente, professor of biology at MIT's Glenn Laboratory for the Science of Aging. "If you have one or two genes that are important for ageing you want them to stand out," he says. "So there has to be some element of scale to be able to find them. What these gene hunters are bringing to the



A sequence of genes is marked as part of research into cancer at the Imperial Cancer Research Fund, London. The aim is to be able to 'switch on' genes that will help the body destroy cancer cells, a goal that could be helped by the likes of Human Longevity Inc




Craig Venter is a firm believer that gathering as much data as possible is the key to teasing out the secrets of ageing from the human genome

table is the technology to be able to analyse big data."

Others are not so sure. Professor Paul Pharoah, director of Cancer Research UK's genetic and molecular epidemiology unit at the University of Cambridge, questions HLI's macro approach. "I'm not sure doing things on such a grand scale is the best way. There's an awful lot of people doing tumour sequencing studies and looking at the associations between cancer and ageing," he says. "What are they [HLI] doing, and what do they know that no one else knows?"

There is a limit to how much our genes can tell us about ageing because whether we get illnesses and how long we live isn't purely controlled by our genes – our environment plays a big part, as do our lifestyles and good old luck.

It's too early to know what secrets HLI has tapped into by hacking human genomes for the last several months. But Dr Kurzrock is convinced that the most revealing insights will come from comparing the genome sequences of her patients at the Moores Cancer Centre with healthy people. "In my work I've seen people in their 30s and 40s who smoke and who already have advanced lung cancer, while other people smoke heavily and still make it to 100 in robust health. Is this luck? I very much doubt it."

Craig Venter firmly believes his approach will drive this area of research further than ever before and is prepared to take a huge, calculated gamble on the success of his venture. "In the last 15 years there have not been that many breakthroughs that have changed medicine. [But with this] I believe we can make giant leaps. If we don't have very substantial breakthroughs in preventative medicines I will be very disappointed. But the odds of that happening are low."

And Venter says success or failure of HLI won't change his approach to life – however long he lives for. "Despite what people think about this whole enterprise I am not in this to live longer or forever. I treat every day as a gift and a challenge. I like to act as if I'm going to live forever, but I treat each day as if I may not and try to live it to the fullest. But that's more of a hope than a prediction."

**LILIAN ANEKWE** is consumer health editor for the weekly medical journal the BMJ

# THE MYSTERY OF THE VOYNICH MANUSCRIPT

The strange book has baffled experts for a hundred years; no one has been able to decipher its text… until now. **Brian Clegg** investigates the riddle

The pages of the Voynich manuscript are littered with strange drawings of astronomical diagrams, plants and nymph-like characters

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The University of Bedfordshire announced in February 2014 that Stephen Bax, Professor of Applied Linguistics, had 'followed in the footsteps of Indiana Jones by cracking the code of a 600-year-old manuscript, deemed the most mysterious document in the world'. If true, a secret that had baffled experts for 100 years was about to be revealed.

The target of Professor Bax's work, the Voynich manuscript, is a hand-written book the size of a paperback. Its 240 parchment pages are filled with an intricate script and page after page of coloured illustrations showing plants, patterns of stars and groupings of squat, naked nymphs. Since its purchase in Italy in 1912 by Polish-American book collector Wilfred Voynich, the book has been an enigma. No one has been able to read the elegant manuscript. Some claim it is a natural language, others a code and most recently that the whole thing is a hoax. Bax's new translation brought the battle over the meaning of this remarkable book back to the fore.

Around two years ago, Bax heard about the book in a radio programme on Elizabethan occultist John Dee, whose association with the manuscript was a long-standing assumption. Voynich believed that his find was the work of Roger Bacon, the 13th Century friar, who wrote copiously on science. According to Voynich, the book reached the hands of John Dee, who sold it to the Holy Roman

PHOTO: BEINECKE RARE BOOK AND MANUSCRIPT LIBRARY

## TIMELINE

### A history of the Voynich manuscript

### 1214-1292

The lifetime of Roger Bacon, initially thought to be the author of the manuscript. This appears to be wishful thinking, and all the evidence now points to a later date.

### 1404-1438

The most likely date range for the manufacture of the parchment of the Voynich, from carbon dating. This does not tell us when the writing was put on the parchment.

### 1586

Holy Roman Emperor Rudolf II is said to have purchased a book written by Roger Bacon for 600 ducats. The dating is largely from the timing of a visit to Europe by John Dee.

Emperor, Rudolf II for 600 ducats (£200,000 in relative earnings.) The claim was based on a letter dated 1665, found with the manuscript.

Bax was joining a long line of professionals and amateurs who had come up against this mysterious manuscript over the past 100 years – yet not one of them has so far produced a convincing solution. Voynich himself never got anywhere, but he was presented with an apparent partial translation nine years after the manuscript was discovered, by Professor William Newbold of the University of Pennsylvania.

Newbold briefly basked in glory before his theory unravelled. He had decided that the script was a blind, and that the actual message was carried in tiny markings above the symbols, which he claimed were similar to an Ancient Greek shorthand. But to come up with his 'translation' Newbold had to take pairs of these characters as single letters, then make anagrams of words. With such complex manipulations of a manuscript it is easy enough to read anything into it. Newbold's translation finally lost credibility when it was shown that the markings were cracking in the ink surface.

Since Newbold there have been many attempts to break through the text. For a while, the favoured hypothesis was that the manuscript was a transliteration of a real language, which merely needed a few keywords to crack it. Then there was the idea it could be a cipher, a message that required decrypting before it could be read. However, it quickly became clear that if this was the case it was a far more complex cipher than any used in the Middle Ages, which are trivial for a modern cryptographer to decode. And finally there was the idea that the book could simply be gibberish. But why go to such effort to make a hoax?

Like many before him, Professor Bax picked out the initial words on the pages showing plant illustrations. Many of these are words used infrequently elsewhere in the text, suggesting they may correspond to the proper names of the plants. One illustration resembles Centaurea, a thistle-like genus of flowering plants. Using a technique similar to that used in decoding Egyptian hieroglyphs, Bax matched letters to the word kantairon, an approximation to a medieval version of the plant's name, encouraged by the appearance of an almost identical word, differing only in the final letter, on the page.

Another clue came from a kind of zodiac, showing a wheel with collections of stars between its spokes. Bax identified a group of seven stars with the Pleiades, hoping that an adjacent word referred to the constellation of Taurus. This is a much weaker gambit, as the Pleiades cluster has a distinct shape, which isn't repeated in these stars. What's more, although the Pleiades are the 'Seven Sisters' of Greek mythology, there are nine major stars in the cluster, including two named after the sisters' parents. The Pleiades cluster is in the constellation of Taurus, but it is quite a stretch to assume this link.

From his word matching, Bax produced transliterations for 14 characters, over half the Voynich alphabet, and has since identified both the castor oil plant and the marshmallow plant. He has speculated that the language may be an otherwise unwritten dialect from western Asia. Other Voynich researchers have pointed out there is an

PHOTO: SCIENCE & SOCIETY, ALAMY X2, SUPERSTOCK, BEINECKE RARE BOOK AND MANUSCRIPT LIBRARY

## 1666

Prague scientist Johannes Marcus Marci writes a letter claiming that a book with mysterious images and text, possibly by Roger Bacon, was sold to Rudolf II for 600 ducats.

oddity in his transliteration as it makes a huge number of the plant names start with C or K. Similarly, plugging the translation into the body text of one page produced a script where around half the words end in R (partly because Bax translates three Voynich letters as R), and many more as N – an unusual distribution for any known language.

Soon after the university went public, these apparent breakthroughs received a challenge from Dr Gordon Rugg of Keele University. Rugg has an interesting and arguably ideal background for analysing

Of all the plants in the book Nigella sativa, or the Fennel Flower, is one of the most clearly depicted in the Voynich manuscript (illustration shown right)

A page from the Voynich manuscript reveals the intricate writing alongside an illustration of a flower thought to be Nigella sativa

## 1912

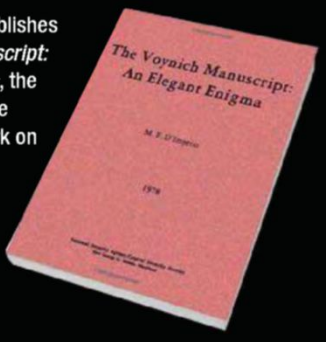
Wilfrid Voynich, a New York-based antique book dealer, purchases the manuscript, which had been found at a villa near Frascati, Italy.

## 1921

William Newbold, Professor of Intellectual and Moral Philosophy at the University of Pennsylvania, claims to have found evidence that Bacon wrote the book in a partial translation of mysterious markings above the characters.

## 1978

Mary D'Imperio publishes *The Voynich Manuscript: An Elegant Enigma*, the first comprehensive monograph on work on the manuscript.




the Voynich. Initially trained in linguistics, he went on to study experimental psychology and now works in computer science. Rugg had two problems with Bax's announcement. One was that this technique had been widely tried since the 1940s without success, and the other was that he believed that the manuscript was not a language at all, but a hoax.

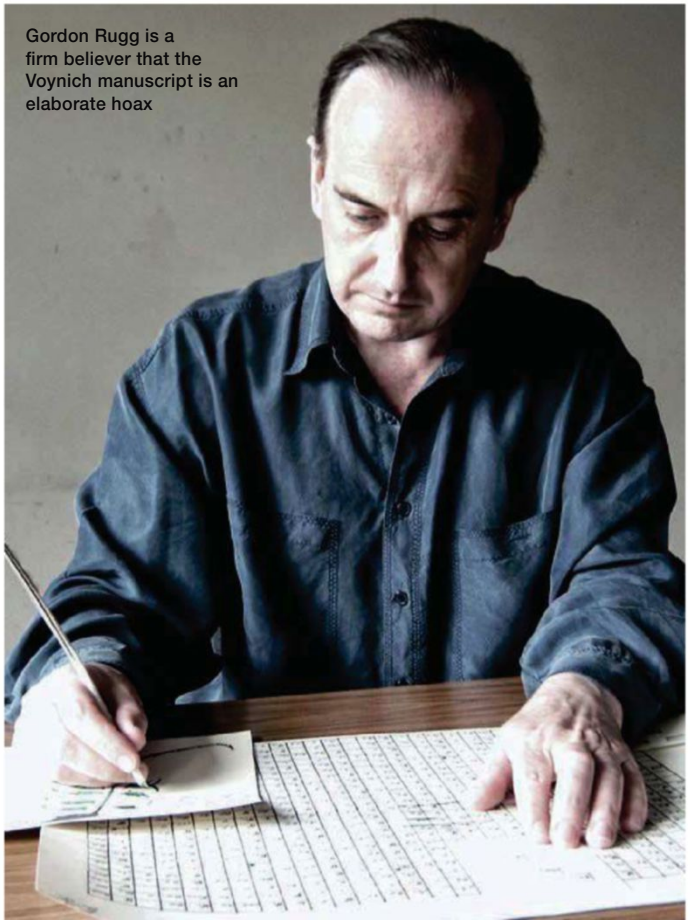
By using technology from the time of John Dee, Rugg has shown that it would be relatively easy to produce a fake Voynich manuscript. In fact Dee's household becomes of particular interest here, as Dee's assistant, Edward Kelley, had already dreamed up an artificial language with its own unique alphabet, known as Enochian. Dee used a number of 'skryers' or mediums, including Kelley, to communicate with spirits. It was Kelley who enabled Dee to apparently use the language of the angels, and Kelley was involved with Dee at the time of the alleged visit to Rudolf II.

Could Kelley produce such a complex manuscript? While it has never given up its secrets, it does have a number of characteristics that suggest it isn't pure gobbledegook. It has a complex, non-random structure. Yet if Kelley could find a way of mocking up such a script, he would have been prepared to put in a good few months of work. If the book was sold for 600 ducats, the equivalent of 8 to 10 years on an average wage, making a fake would have been worth it.

To create such a document you would need a mechanism for generating fake words. Using quill pens and parchment, Rugg demonstrated how easily this could be done, starting with a large table of word segments and combining them using a cut-out grid to avoid sequential repetition. Using this technique and hand drawing, Rugg reproduced an illustrated plant page in around two hours, meaning the book might take 10 weeks to construct, a respectable amount of time. This technique could also pass the statistical test applied to the manuscript by Marcelo Montemurro of the University of Manchester in 2013, contradicting an Austrian statistical analysis from 2007 that declared it gibberish. The Manchester technique maps 'high information words' and suggests that the Voynich has meaning, but could also work with a fake using Rugg's approach.

In principle such a hoax might have been undertaken at any point in history, although the use of these grids in producing ciphers, making them a natural technique for mocking up a fake language, was only introduced in the 1550s. One obvious clue would seem to be carbon dating, and in 2010 a team from the University of Arizona declared that the parchment was most likely to have been produced between 1404 and 1438, much

**"The book was sold for 600 ducats, the equivalent of 8 to 10 years on an average wage"**



Gordon Rugg is a firm believer that the Voynich manuscript is an elaborate hoax

PHOTO: ALAMY X2, UNIVERSITY OF PENNSYLVANIA ARCHIVES, SIMON WESSON

## 2012

Stephen Bax comes across the Voynich manuscript in a programme about John Dee (pictured) on BBC Radio Four.

## 2013

Gordon Rugg publishes Blind Spot, a book describing techniques to analyse errors in expert decisions, using the Voynich and the possibility that it is a hoax as a major case study.


## 2014

Stephen Bax gives us the first few words in the latest attempt to uncover the secret of the manuscript.

earlier than the 1586 date when the manuscript may have been sold to Rudolf.

It doesn't, however, rule out Kelley as the author. It wasn't uncommon for parchment to be kept for decades before writing on it, and it would be easy enough to take an old, part-used book, remove the pages that had been written on and make use of the rest. To cover this up, the manuscript might then be rebound out of order so that the lost pages weren't all at the front of the book – and, interestingly, the Voynich manuscript does appear to have been bound with the pages rearranged. If old parchment was used, it allows for an even more dramatic hoax suggestion – that Voynich himself was behind it.

This has been suggested by Voynich researcher Richard SantaColoma. He believes that Voynich found the letter giving the book's provenance and created a manuscript to match. If it had been nothing more than an obscure herbal manual, it would not have been worth the effort, but here there was the combination of the intriguing mystery language and the alleged link to Roger Bacon, who was in the news in 1912 as his 700th anniversary approached, a link that Voynich stressed. This made it possible for the book dealer to value the manuscript at $100,000.

### Elaborate hoax?

There's more that adds weight to the hoax theory. The manuscript features unusual word repetition. One phrase, for instance, transliterated into familiar letters in a convention used by Voynich researchers, reads 'qokedy qokedy dal qokedy qokedy'. Conversely, it's very unusual in the manuscript to find frequently used phrases with two or three words together, something that occurs in most languages.

Then there is the absence of mistakes. In a notebook, with the lack of formality of the Voynich, you might expect to see crossings out, and even the best medieval manuscripts contain corrections. When a scribe made an error, he would wait for the ink to dry, then scrape it carefully off the parchment before writing the new characters. However carefully done, this action leaves a mark on the surface of the material. A few years ago an examination was made of extremely high-resolution images of several of the Voynich pages, providing far more detail than is obvious to the naked eye – yet there was no evidence of a single correction.

It isn't possible to give a definitive answer on the Voynich manuscript unless a solution provides a full decoding. Stephen Bax's translations are interesting, but as yet he has not said which language he believes the manuscript is written in, nor has he been able to apply his transliterations to the text as a whole. Meanwhile, Gordon Rugg's hoax hypothesis is intriguing, but could only ever be proved if supporting evidence from the period of the forgery were discovered.

What remains is a delightful enigma, that will no doubt prove as entertaining in the next hundred years as it has in the first.

**BRIAN CLEGG** is the author of *Dice World: Science And Life In A Random Universe*

## FOR or AGAINST:

### Is the Voynich manuscript fake?

**⊖ Stephen Bax**

**Professor of Applied Linguistics at the University of Bedfordshire**

"The attraction for me personally was the oddity of the script and the possibility that it might be a script that I could decode. Many people have looked closely at the script and discounted that it might be a natural language. I've looked closely at it, taking full account of what they say, and I believe as a linguist that it could well be a natural language."

**⊕ Gordon Rugg**

**Senior Lecturer in Computer Science at Keele University**

"One key assumption that everybody made is that complex structures need to have complex causes. There are complex structures within Voynichese, so everyone had thought that it couldn't be a hoax because those structures were so complex… But very simple causes can produce very complex outcomes."

A pair of azure-blue Lear's macaws fly past their red sandstone nesting cliffs in the arid interior of north-east Brazil

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# Brazilian BLUES

The recovery of Lear's macaw, one of the world's most beautiful parrots, has startled the 'triage conservationists' who suggest that trying to save species with tiny populations is a waste of time, says **Tony Juniper**

Photos by **João Marcos Rosa**

For most people, their first thought of Brazilian forests is of dense, steamy jungles. Far fewer know about the thorny thickets in the arid and drought-prone north-east of this enormous country. But though they might appear desolate and inhospitable, these haunting woodlands, known as caatinga, are as Brazilian as the Amazon rainforests – and surprisingly rich in endemic wildlife.

I explored these parched, spiny forests in 1990, searching for Spix's macaw. I was working with the International Council for Bird Preservation (now BirdLife International), where my job was to help prevent the extinction of the world's endangered parrots, and this was the rarest of the rare. Spix's macaw was known to be near the edge, but just how near came as a severe shock: my Brazilian colleagues and I sadly concluded that there was just a single bird left in the wild – a solitary male.

Spix's was one of four impressive blue South American macaws that tragically were all high on the list of parrots for conservation action (see box, below). In fact the glaucous macaw, known from far further south, had most likely already crossed the line of extinction. The hyacinth macaw, the biggest parrot of all and known to live chiefly in Brazil's interior, in areas such as the Pantanal seasonal wetlands, was doing somewhat better. But even that species was down to just a few thousand birds.

**Helmut happened to meet a hunter who had shot a blue parrot to eat and, fortunately, had kept some of its feathers**

The fourth species, Lear's, had for a long time been known only from museum specimens and birds that had turned up in captivity. In common with the glaucous and hyacinth macaws, it had a massive palm-cracking beak, a very long tail and long, graceful wings. Like Spix's, it was believed to be possibly extinct – but all that changed in 1978 when, after decades of speculation, a wild population was located by Brazilian zoologist Helmut Sick.

I met Helmut in Rio de Janeiro in 1990, where he told me about his dogged quest for Lear's macaw. He explained how he'd mounted several expeditions to look for the species in north-east Brazil, starting in 1964. The vast search zone covered an area larger than France, and it was only 14 years later that he eventually struck gold.

### Finding the holy grail

Helmut discovered his macaws in a remote area called the Raso da Catarina, in the sun-baked, rugged interior of the state of Bahia, not far from where our own expedition was later to find the last Spix's macaw. He described this inhospitable place as "a great white patch on the map, far, far away from the nearest civilisation". The trackless landscape was too much for even the best 4WD vehicles, so Helmut had to search on horseback.

It was in this unforgiving, far-flung land that Helmut came across the vital clue. In 1978 he happened to meet a hunter who had shot a blue parrot to eat and, fortunately, had kept some of its feathers. Helmut had recently returned from Santiago Zoo in Chile, where he had studied captive Lear's macaws, making detailed notes and measurements. So when he clapped eyes on the poor bird's remains, he instantly knew that he'd found his Holy Grail.

On 31 December 1978 Helmut at last tracked down a population of about 60 Lear's macaws. They were living ▶

## THE FOUR BLUES: WHERE ARE THEY NOW?

### LEAR'S MACAW
Endangered

Once believed to be a hybrid between the larger hyacinth macaw and the paler glaucous macaw, this species was first described in 1856 by French ornithologist Lucien Bonaparte, based not on a live bird but on an 1832 artwork by Edward Lear. Until 1978 it was known only from captive birds and those in museum collections.

### HYACINTH MACAW
Endangered

These huge parrots – the world's biggest, measured from beak to tail-tip – range across the dry interior of Brazil and into Paraguay and Bolivia. The largest of three main populations is centred on the Pantanal region, where there are some 5,000 individuals. Popular with collectors; under relentless pressure from trappers.

### SPIX'S MACAW
Probably extinct in the wild

What was probably the last wild bird was seen in 1990 – tantalising but unproven reports suggest a few birds may just hang on in Brazil's Serra da Capivara National Park, in the state of Piauí. The captive population of about 96 birds might yet one day lead to a reintroduction attempt in the few remaining areas of habitat.

### GLAUCOUS MACAW
Extinct in the wild

Believed extinct since the 1960s, this bird was more turquoise than Lear's, but a new study aims to establish whether it was simply a form of the same species. If so, this would effectively extend the known range of Lear's macaw south as far as northern Argentina, justifying releases of captive-bred Lear's there in future.

Spix's: Luiz Claudio Marigo/NPL; hyacinth: Nick Garbutt/NPL; glaucous: Julian Hume/WAC/NPL

Pockmarked cliffs at Raso da Catarina provide safe nest sites. The macaws breed from February to April, raising one or two young

**Research is underway to better understand feeding patterns, reproduction and the size of their home ranges**

Lear's macaws form pairs before they are old enough to breed, and mates stay together for life

on steep red sandstone cliffs where they roosted and nested.

This tiny group of birds was under relentless pressure from trappers, including the same man who had single-handedly almost wiped out the last remnant group of Spix's macaws. The phenomenal value of Lear's macaws, even back then selling for over $10,000 each, meant that big incentives were on offer for those who could catch them. The favoured method was to lower nets down over cliff-faces. As the macaws attempted to leave, they'd become entangled, be hoisted upward and embark on journeys to collectors on the other side of the world.

The birds were not only at risk from trappers – their main food source, the fruits of licurí palms, was under pressure as well. The palms were being cleared for cattle pasture and being lost in periodic wild fires. Only a few pairs of birds were found to be breeding – and because of feather deformities, it was feared that inbreeding was already taking a toll. Though a further small population was later discovered, the total number of birds was perilously tiny.

It wasn't clear why this species was so rare, but Carlos Yamashita, a Brazilian expert on parrots, told me he thought it might be because a long-standing relationship with other South American wildlife had been severed. He suspected that the giant ground sloths that once roamed South America, and which had been wiped out by early human hunters, ate palm nuts and their dung provided food in an easier form for the macaws to eat. But whatever the reason for its scarcity, there was little doubt that Lear's macaw was in imminent danger of extinction. It was duly listed as Critically Endangered – the last stop before disappearing completely.

This stunning landscape is part of Serra Branca Farm, whose owner has turned it into a major stronghold for Lear's macaws

## Poet's parrot

Helmut's discovery transformed the macaw's status overnight. It had long been a 'poet's parrot', with an English name that honoured Victorian artist and poet Edward Lear. A famous painting of the bird included in his 1832 book, Illustrations of the Family of Psittacidae, or Parrots, had helped the moniker to stick. But now what had been an obscure creature in ornithological circles, known only from old paintings, a few captive individuals and mothballed skins, suddenly became a very rare wild bird with a known home range. And that had massive conservation implications.

An urgent rescue effort was launched. Guards were stationed at the macaw nesting cliffs and a modest-sized protected area was established. Despite this, the capture of birds continued. In 1992–1995, for example, it was estimated that 20 individuals were caught and sold from one population. In 1996 alone at least 19 were taken.

The conservation effort was stepped up, and the protected area expanded. In 2007 a Brazilian conservation group called the Biodiversitas Foundation, with assistance from the American Bird Conservancy, bought neighbouring properties to enable a ten-fold increase in the size of the Canudos Biological Station. The new reserve covered 1,450ha, including the cliffs where about half of the surviving birds roosted and nested. "It was a huge step towards the preservation of the species," says Eduardo Figueiredo of the Lear's Macaw Conservation Program.

There are ongoing efforts, supported by the Tenerife-based Loro Parque Fundación, to safeguard groves of the licurí palms that provide most of the macaws' food. Some areas have been fenced off to prevent them being trampled by cattle. But maintaining the food supply for the birds is no small task, when an estimated 450 fruit-bearing palms are needed to sustain a single macaw.

Sometimes the macaws raid farmers' corn, triggering persecution, so conservationists have been offering financial compensation. Research is also underway to better

The fruits of the licurí palm are the macaws' main food: their fortunes are closely tied to those of the tree

understand the birds' feeding patterns, reproductive biology and the size of their home ranges. Surveillance at breeding sites has moved up a gear and arrests have been made.

Progress has been exceptional. From a minuscule, barely viable known population of 60 or so birds in the late 1970s, there were close to 250 by 2001. There were 400–500 in 2004, and in 2006 an estimated 630. In 2008 there were nearly 1,000 macaws. A survey conducted in November 2013 suggested that there were almost 1,300, a slight increase on the year before, despite a severe drought that it was feared might affect their breeding.

The surge in numbers has encouraged conservationists to downgrade the species' status to Endangered. It's still a precarious position, but the deep, red canyons clothed in thorny caatinga woodland and cactus scrub echo once more with the screeches from flocks of these amazing parrots.

Challenges remain – not only when protecting the wild birds, but also when making best use of macaws in captivity. At least 74 are scattered across the globe in private collections and public zoos. These birds could be valuable to the conservation effort, but no coherent captive-breeding programme exists, despite decades of trying.

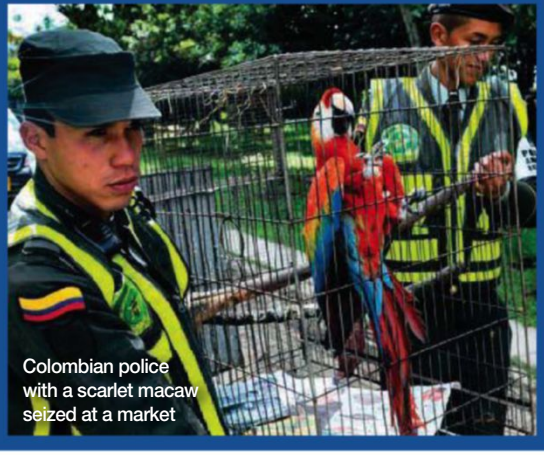
"Lear's macaw is a great example of a species that 'triage' theorists might have said we should let go," says Michael Parr of the American Bird Conservancy, referring to the way in which doctors prioritise between patients, sometimes leaving those for whom there is nothing else that can be done. "Thankfully the local conservationists at Biodiversitas thought differently."

## FATAL ATTRACTION: THE CAGEBIRD TRADE

Parrots have been popular companion birds for a very long time. Over 2,300 years ago Alexander the Great brought some back to Europe from his travels to the Indus Valley (this is how the Alexandrine parakeet got its name). Today much of the demand is met by captive breeding, but some species – especially the scarcer ones – remain at grave risk from trapping in the wild.

Parrots now rank among the most threatened of all bird families. The IUCN currently lists 100 of the world's 330 species as At Risk. Of these, 66 species are directly threatened by the illegal bird trade, including all three of the surviving blue macaws.

The trade in all parrot species is governed by the Convention on International Trade in Endangered Species (CITES). Despite this and additional measures including a ban on the import of wild birds introduced by the USA and EU, huge financial incentives continue to drive illegal trade in these attractive, charismatic birds.



Colombian police with a scarlet macaw seized at a market

Mauricio Duenas/AFP/Getty

### The birds came back

That such a large, colourful and noisy parrot could for so long evade detection says something profound about our knowledge of the world. Its recovery provides an important lesson, too. Determined fieldwork followed by conservation action involving local communities can rescue even the most endangered species. Lear's poem Calico Pie comes to mind:

*The little Birds fly*
*Down to the calico tree,*
*Their wings were blue,*
*And they sang "Tilly-loo!"*
*Till away they flew, –*
*And they never came back to me.*

In this case, amazingly, the birds did come back.

**TONY JUNIPER** is an environmentalist and former director of Friends of the Earth. His books include Spix's Macaw: *The Race To Save The World's Rarest Bird* and *What Has Nature Ever Done For Us?* Visit www.tonyjuniper.com to find out more.


ILLUSTRATOR: MAGICTORCH

A material that defies gravity would transform transport, energy and even the weather. **Paul Parsons** examines the latest progress in the experiment that could find it

The Hg Wells novel The First Men In The Moon, published in 1901, saw human beings travel from Earth to our planet's natural satellite in a spacecraft powered by 'cavorite'. This was a fictional antigravity material, capable of blocking the Earth's gravitational pull. For centuries, scientists and philosophers have pondered this problem – how might we counteract gravity, that most fundamental of the forces, which keeps us all stuck firmly to the Earth's surface?

Of course, aircraft and space rockets manage to overcome gravitational pull, but only at considerable cost and effort. True antigravity would allow a vehicle to rise gracefully upwards at the flick of a switch – not just overcoming gravity, but altering its very essence. Now, antigravity may be about to make the leap from science fiction to science fact. Earlier this year, a team at CERN – the European centre for particle physics, on the border between France and Switzerland – announced plans to look for signs of antigravity in particles of antimatter.

## Falling upwards

Antimatter can be thought of as the opposite of ordinary matter – with all its key properties, like electric charge, reversed. All properties except one, that is. Matter and antimatter both have positive mass, so most physicists had expected them both to behave in the same way when placed in a gravitational field. But now scientists at CERN say this might not be the case after all. They think antimatter might fall at a different rate to ordinary matter – and could even 'fall upwards'.

"Is there such a thing as antigravity? Based on free-fall tests so far, we can't say yes or no," says team member Prof Joel Fajans, of Lawrence Berkeley National Laboratory (LBNL), California. "We certainly expect antimatter to fall down, but just maybe we will be surprised."

Their tests involve an experiment at CERN called ALPHA (short for Antihydrogen Laser Physics Apparatus). The experiment combines antiprotons with antielectrons to make antihydrogen atoms, which are stored briefly in a magnetic field. When the field is switched off, the atoms fall out and move under the action of gravity until they collide with the walls of the apparatus.

When this happens, a flash of light is given off. By looking at when and where these flashes occur in the ALPHA experiment, the scientists are able to get a handle on how the antihydrogen atoms are falling in the Earth's gravitational

field. Making these measurements, however, is not straightforward. There's much uncertainty owing to the unknown starting positions and speeds of each antihydrogen atom when the magnetic field is switched off. At present, this statistical error is 100 times the size of the expected measurements. "We need to do better," says Prof Jonathan Wurtele, also of LBNL. "We hope to do so in the next few years."

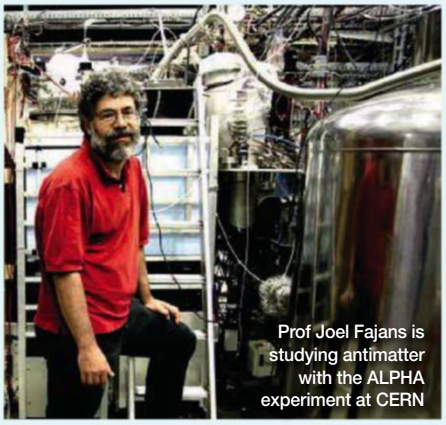
To that end, the equipment at CERN is now being upgraded. When complete, ALPHA-2 will incorporate a laser cooling system to reduce the energy of antiatoms – so that their speed and position can be more precisely determined. If ALPHA-2 does show matter and antimatter to be falling at different rates, it could be time to rewrite the textbooks on gravity. "That would be new physics," says Dr Michael Doser, of CERN. "While there are not many viable models, a number have been developed which would allow additional gravity-like forces, or modified forms of gravity between matter and antimatter."

## WHAT IS ANTIMATTER?

### The Universe's yin-yang nature

Matter is made of particles such as electrons and protons. But each type of particle has a counterpart with opposite electric charge: antimatter. Antimatter was postulated in 1928 by British physicist Paul Dirac, who had deduced a new theory of the electron. It predicted the existence of positively charged antimatter electrons, now known as positrons. Antimatter was first observed in 1932 and is now regularly made in particle accelerators. When matter meets antimatter the two annihilate, turning their mass into energy. In 1996 scientists put an antiproton and a positron together to make antihydrogen - the world's first antiatom.

While Earth-bound experiments are ongoing, so are searches further from home. Astronomers have found something that most definitely is falling up – galaxies lurking at the edge of our observable Universe. The ordinary matter filling our expanding Universe creates attractive gravity. It was thought this gravity would slow down the cosmic expansion. But when, in the late 1990s, astronomers studied galaxies at different distances from Earth – seen as they were at different cosmic epochs (because of the finite speed of light) – they were in for a surprise. The expansion wasn't



Prof Joel Fajans is studying antimatter with the ALPHA experiment at CERN


The ALPHA-2 experiment is installed at CERN – it will be able to spot any antigravity properties that antimatter might have

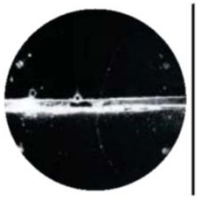
PHOTO: PENNY BRADFIELD, CERN X2, NASA, SCIENCE AND SOCIETY, PRESS ASSOCIATION

**1915** Albert Einstein publishes the General Theory of Relativity (GR), which remains our best description of gravity.

**1917** Using GR to build a model of the Universe, Einstein proposes the 'cosmological constant', later known as 'dark energy'.

**1921** American physicist Thomas Townsend Brown discovers the 'ionic wind' effect that causes 'lifters' to levitate (see pxx).

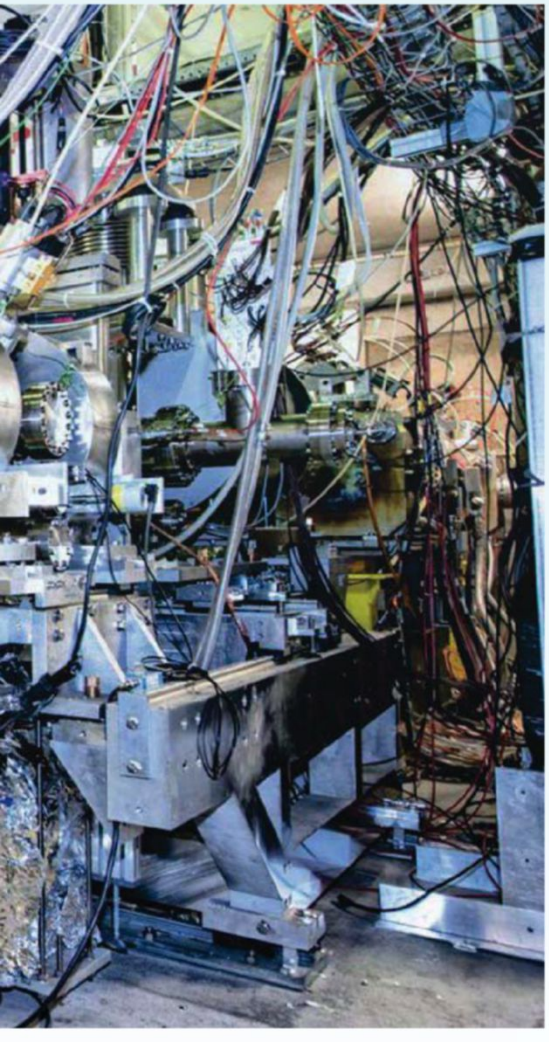
**1932** Carl David Anderson discovers the positron, the first known antimatter particle, predicted four years earlier by Paul Dirac.



**1933** Walther Meissner and Robert Ochsenfeld find that superconductors can levitate magnets.

**"We certainly expect antimatter to fall down, but just maybe we will be surprised"**

Professor Joel Fajans, of Lawrence Berkeley National Laboratory



slowing down at all, but was actually getting faster. Distant galaxies were accelerating away from us, and the astronomers concluded that some kind of antigravitating material must be responsible.

They called this material 'dark energy'. It's actually an old idea. In 1917, shortly after Einstein had formulated his General Theory of Relativity, he used it to build a model of the Universe at large. But his calculations quickly revealed the model to be unstable, recollapsing under its own gravity. To solve the problem, Einstein added dark energy (although it wasn't called that at the time) to his model – essentially an antigravity-like term in the equations governing his theory. In 1929, when American astronomer Edwin Hubble found that space was expanding, Einstein removed the dark energy term from General Relativity. But by the end of the century, astronomers had found that Einstein's 'biggest blunder' (as he called it) is in fact a real feature of our Universe.

### In the dark

Last September, UK astronomers announced a new project, called the Dark Energy Survey (DES), to map the distribution of dark energy throughout space – and to chart how this distribution has changed as the Universe evolved. Although dark energy is invisible, astronomers can infer its presence through its anti-gravitational influence on distant galaxies and the light that they emit. Over a period of five years, DES will survey 300 million galaxies in an area covering one-eighth of the night sky.

The study will help scientists better understand the nature and ultimate origin of this curious substance. "We know dark energy exists, but that's about it. How this substance changes with time and location remains unclear, but we'll have a better view after DES," says team member Dr David Bacon, of the University of Portsmouth.

An extreme form of this antigravitating dark energy is believed to have existed shortly after the Big Bang. Called 'inflation', it prevented the embryonic Universe from recollapsing back on itself –

## WHAT WILL WE DO WITH ANTIGRAVITY?

**A technological revolution awaits when we finally master this bizarre phenomenon**

### TRANSPORT

With no need to fight the downward pull of gravity, aircraft will be able to skirt around the Earth at high speed and at a fraction of the cost.

### CHEAP ENERGY

Water flowing downhill can generate energy. If you could get the water back to the top of the hill with minimal effort you could generate the same energy all over again.

### SPACE FLIGHT

Cosmologist Hermann Bondi showed that if you placed antigravitating matter next to normal matter then the two will 'self accelerate'. Robert Forward suggested this could be used to build a space drive.

### WEAPONS

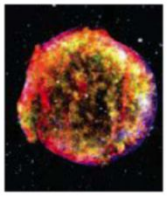
Antigravity will make it easy to reach orbit. Throw a big rock down from space and it will strike the ground with the force of a nuclear bomb.

### WEATHER CONTROL

Altering gravity would have an effect on atmospheric pressure. This in turn could enable us to control the weather, for example to prevent hurricanes.

**1996** Russian Eugene Podkletnov claims to have found evidence for gravity shielding in spinning superconductors.

**1999** Supernova explosions provide the first evidence for the existence of dark energy.



**2000** The first superconducting maglev train (using the Meissner effect) is successfully tested by scientists in China.

**2002** Stories emerge of NASA attempting to reproduce Podkletnov's work to build antigravity craft.

**2013** Physicists at CERN announce details of experiments to discover whether antimatter possesses antigravitating properties.

# UP IN THE AIR

The world of antigravity is filled with lofty concepts. Here are some key terms to help you get off the ground

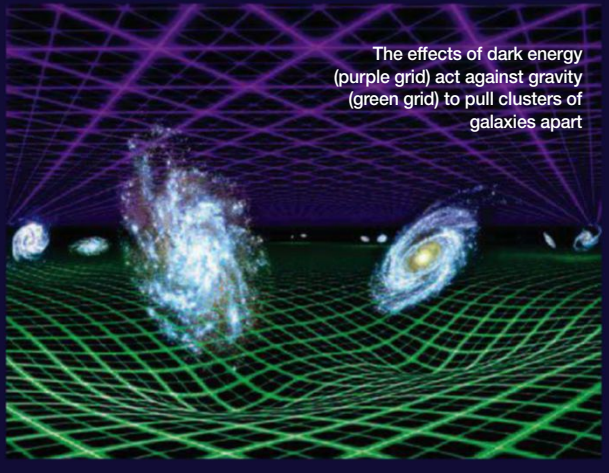
Gravity shielding technology could be used to power flying saucer-like craft

## GRAVITY SHIELDING

Russian physicist Eugene Podkletnov claims to have created a device that can partially block the force of gravity. If correct, this would be an example of 'gravity shielding', with the device able to screen out the particles carrying the gravitational force, much like a screen of lead can block particles of radiation like X-rays.

## REPULSIVE GRAVITY

The gravitational force between lumps of ordinary matter is always attractive, pulling the objects together. But some forms of matter generate repulsive gravity, whereby the gravitational force pushes objects apart. An example is 'dark energy', which cosmologists believe is causing the expansion of the Universe to accelerate.



The effects of dark energy (purple grid) act against gravity (green grid) to pull clusters of galaxies apart

An artist's impression of a string, which forms the basis of string theory

## ALTERNATIVE GRAVITY THEORIES

It may be that Einstein's General Theory of Relativity is not the last word on gravity. Another, deeper physical law may lie beneath, such as string theory. If we find in experiments that antimatter demonstrates antigravitating behaviour then an alternative gravity theory could be the best explanation.

PHOTO: CORBIS, FERMILAB, ALAMY, SCIENCE PHOTO LIBRARY X2

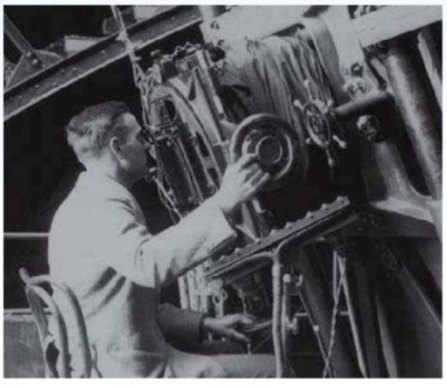
**"We know dark energy exists, but how this substance changes with time and location remains unclear"**

Dr David Bacon of the University of Portsmouth

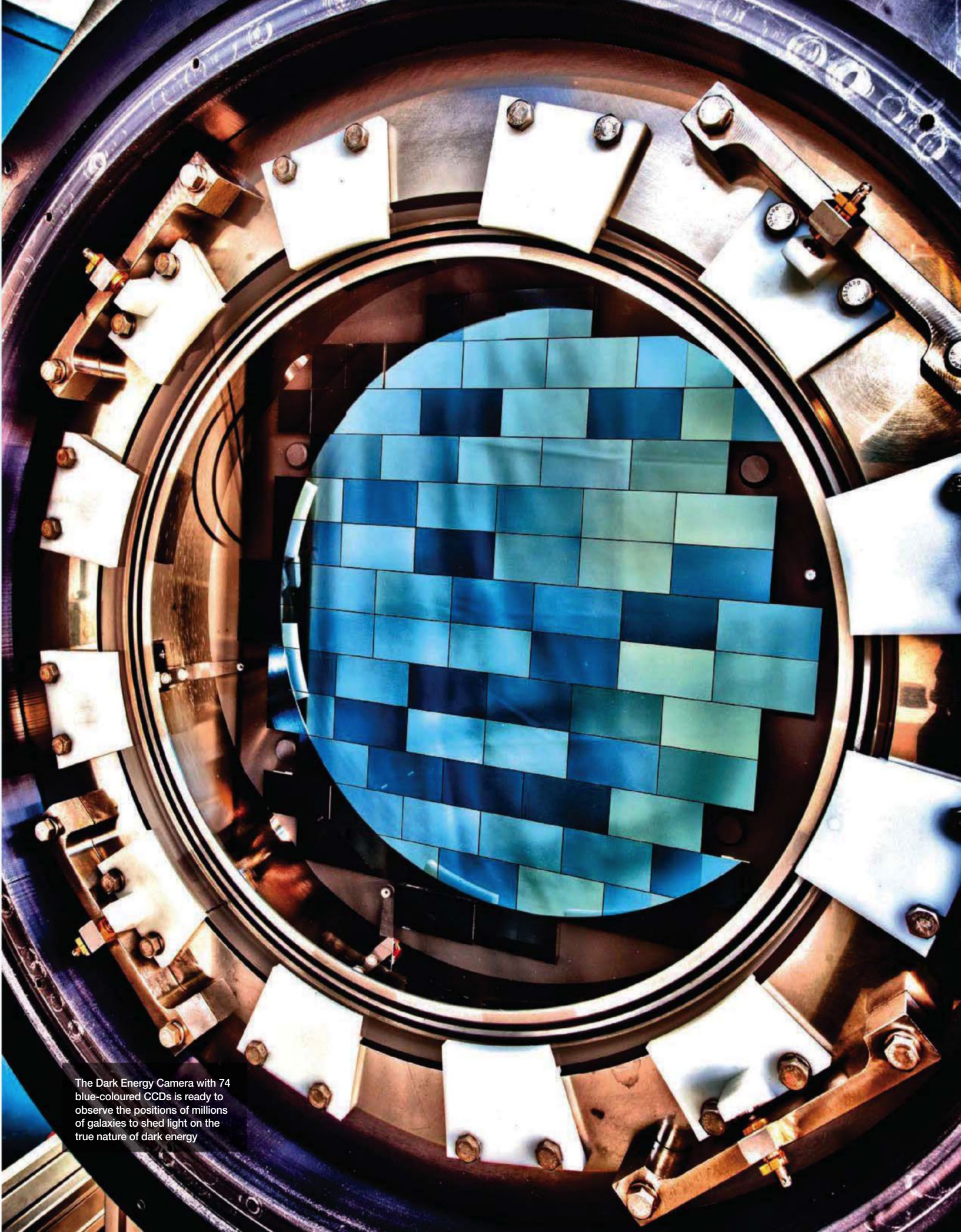
instead blasting it up from microcosm to macrocosm in the tiniest fraction of a second.

Indeed, that we are here at all is at least partially thanks to inflation and dark energy. If the precise amount of dark energy was different, the Universe wouldn't evolve in the same way. "In [models of] universes that have much more dark energy than ours, whenever matter tries to clump into galaxies, the repulsive push of the dark energy is so strong that it blows the clump apart and galaxies don't form. Universes with much less dark energy collapse back on themselves so quickly that, again, galaxies don't form," explains physicist Prof Brian Greene, of Columbia University. "Without galaxies there are no stars, no planets, and no chance for our form of life to exist."

We don't need to look into space to see antigravity in action, however. Experimental physicists have already created small amounts of antigravitating material in the lab, and it has nothing to do with antimatter. In the so-called Casimir effect, named after Dutch physicist Hendrik Casimir who discovered it in 1948, negative energy is created between two metal plates positioned just a few billionths of a metre apart in a vacuum – causing the plates to move together. This happens because empty space isn't really



Edwin Hubble discovered that the Universe was expanding



The Dark Energy Camera with 74 blue-coloured CCDs is ready to observe the positions of millions of galaxies to shed light on the true nature of dark energy

empty at all. It's actually a bubbling mass of virtual particles popping in and out of existence over very short timescales. According to quantum theory – the physics of the subatomic world – particles can equally be thought of as waves. Outside the plates, waves of all possible wavelengths can exist. But between them the waves are rather like vibrating strings – the only vibrations allowed are those for which the length of the string is a whole number of half wavelengths. Converting back to particles, this means that there is less energy between the plates than there is outside. If the outside is a zero-energy vacuum then the inside must have negative energy. And this creates antigravity.

The Casimir effect was verified experimentally in 1997 by Steve Lamoreaux, at Los Alamos National Laboratory. However, the amount of negative mass created was tiny – around -10–27 grammes. That's just one ten-millionth (0.0000001) of the force needed to lift a car. In 2009, experimental physicists at Harvard University measured a repulsive analogue of the Casimir effect – which pushes the two plates apart rather than pulling them together. This is possible by varying the materials that the two plates are made from and adding a fluid between them. The 'anti-Casimir effect' can levitate objects, and will

**"There is important, potentially revolutionary research into the phenomenon of antigravity"**

be a significant breakthrough in nanoscale engineering (where attractive Casimir forces can create unwanted friction between moving parts). However, the anti-Casimir effect has nothing to do with modifying gravity itself and so isn't antigravity in the strictest sense.

Antigravity is one of those fields where amateur scientists frequently feel the urge to contribute. The post bags at regularly bring designs for antigravity machines from inventors, many of whom haven't subjected their creations to adequate testing themselves, let alone the independent scrutiny required to convince a professional scientist.

The place to send an idea for defying the force of gravity isn't a popular science magazine like ours but a scientific journal,

PHOTO: FERMILAB, U MOHIDEEN/UC RIVERSIDE, NASA, PETER TERREN/TESLADOWNUNDER.COM, ALEX NEEDHAM/WIKI

# DEFYING GRAVITY

**In the absence of a bona fide antigravity effect, here are three other ways to make things float**

Catch a floating train from Pudong airport to Shanghai, China

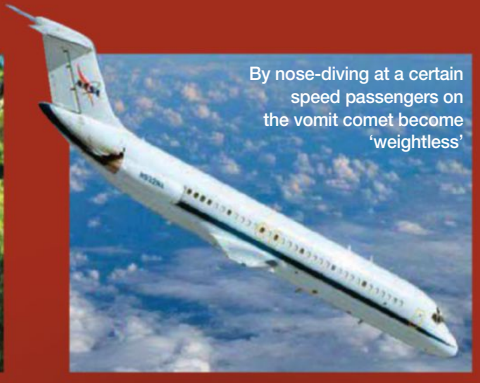
## MAGLEV

Some high-speed trains forsake wheels in favour of magnets, using the magnetic force to make the train hover above the track, massively reducing friction. As with lifters, this so-called maglev technology isn't true antigravity. The most modern maglev trains use powerful superconducting magnets.

Lifters use a downward wind of charged particles to take off

## LIFTERS

Technically these aren't antigravity; they just look like it. A lifter is a triangle of balsa wood covered in tin foil, with a length of thin wire stretched round posts at each vertex. Apply a high voltage (typically 30,000V+) across the foil and the wire creates a downward wind of charged particles, causing the lifter to hover. Don't try this at home!



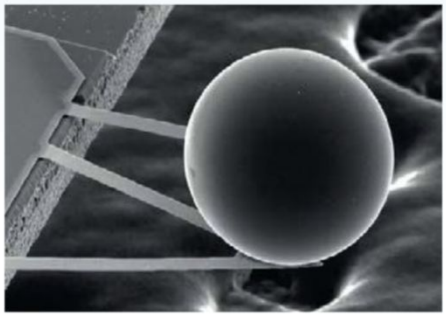
By nose-diving at a certain speed passengers on the vomit comet become 'weightless'

## VOMIT COMET

Aircraft such as the NASA 'vomit comet' can reduce the gravity experienced by occupants by nose-diving at a rate equal to the acceleration caused by Earth's gravitational pull. A similar technique is used in 'drop-towers' to create a simulated zero-gravity environment for science experiments.

Scientists put together a prototype of the Dark Energy Camera, which will record the positions of 300,000,000 galaxies

whose editors will subject it to rigorous peer review before deciding whether or not it merits publication. One researcher who did just that was Russian physicist Eugene Podkletnov. In a paper accepted for publication in 1996 by the Journal Of Physics D (though subsequently withdrawn by its author), Podkletnov reported that objects he placed above a spinning superconducting disc lost 2 per cent of their weight. He was careful to stress that he had accounted for other effects such as air currents and magnetic phenomena.



In an experiment at the University of California, this microscopic ball demonstrates the Casimir effect; the reverse effect can levitate objects

Nevertheless, many regard Podkletnov as either deluded or dishonest. That's because in the 17 years since his paper, no one has been able to replicate his claimed results and not for lack of effort. Teams from international universities and organisations like Boeing, BAE Systems, and even NASA have tried but failed.

"I undertook the first serious attempted replication of Podkletnov's work while I was on the academic staff at Sheffield University," says Clive Woods, now a professor of engineering at Louisiana State University. "We saw no effects ascribable to gravity modification by the spinning superconductor." Prof Woods explains that he was simply unable to recreate the extreme experimental conditions that Podkletnov claims to achieve in his paper. "No one, as far as I know, has managed to reproduce all the required and published conditions and measure a result," he says. "The general conclusion seems to be that it is a wild goose chase." We emailed Podkletnov for comment. He replied, sending a lengthy and technical electronic book on his work, but declined to tell us whether his research had been independently verified.

Yet there is important, potentially revolutionary research into the phenomenon of antigravity. If science can crack and harness the secrets of this perplexing field, they could lead to breakthroughs in transport, energy generation, spaceflight and even weather modification. Ever since the time of Sir Isaac Newton, the laws of physics have insisted that apples fall downwards and not up. Now, that might just be about to change.

**DR PAUL PARSONS** is a former editor of BBC Focus and the author of *How To Destroy The Universe* (Quercus)

## ANTIGRAVITY FAQ

Prof Clive Woods of Louisiana State University and Dr Michael Doser of CERN clear up some tricky questions

**Would antigravity vehicles need a counterbalancing force to stop them flying off?**

"I think it depends on what the hypothetical antigravity system does," say Prof Clive Woods. "If it is antimatter of some sort, then to keep the vehicle on the ground you'd need an opposing force downwards – but then out in space you would need a rocket to give propulsion."

**Would antigravitating matter fall up?**

Not necessarily. This all comes down to an idea in physics called the 'weak equivalence principle', which says that all objects fall at the same rate in a gravitational field – and which our current understanding of gravity is built on. "This is precisely what our experiment will test," says Dr Michael Doser. "If antimatter were to fall differently from ordinary matter in the Earth's gravitational field, that would be new physics."

**Could you use antigravity to propel spacecraft?**

Some pretty outlandish-sounding ideas for antigravity spacecraft propulsion have been suggested. "These spacecraft drives alter the space-time fabric in peculiar ways so that the vehicle is constantly 'falling into' a hole, giving propulsion, and if this could be produced and controlled then presumably you wouldn't need a rocket," says Prof Woods.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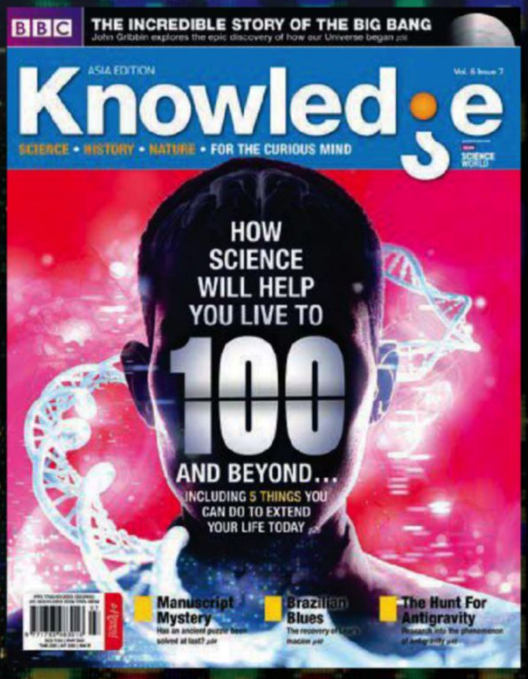


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# THE UNIVERSE STARTED WITH A BIG BANG

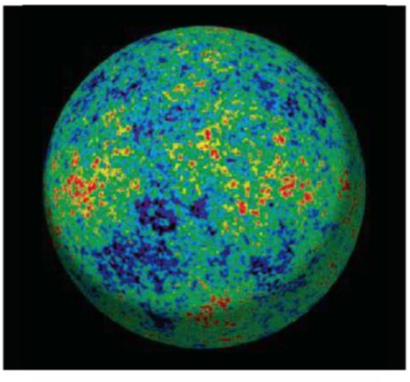
## BY JOHN GRIBBIN

**Finding the heat signature of a cataclysmic explosion turned out to be proof that our Universe expanded from a single point. It would prove be one of humanity's greatest discoveries**

The idea that the Universe was born in a hot, dense state – the Big Bang, as Fred Hoyle dubbed it – is one of the most important, and well-established, scientific concepts. But the idea is less than a hundred years old, and The Beatles were already the singing sensation of the 1960s before astronomers had proof that there really was a Big Bang. Fifty years ago, solid evidence was found in the form of the so-called Cosmic Microwave Background Radiation. By then, though, there was already plenty of circumstantial evidence.

With hindsight, we can see the genesis of the Big Bang idea in a paper published by the Russian mathematician Alexander Friedmann in 1922. Friedmann realised that the equations of Albert Einstein's General Theory of Relativity, which describe the behaviour of space, time and matter, allowed for the possible existence of different kinds of universe. Some started out small and expanded as time passed. Some started large and shrank as time passed. Some grew from a tiny point out to a certain size then collapsed back into a point, perhaps 'bouncing' into another cycle of expansion and collapse. At the time, there was no firm evidence that any of these mathematical models matched the Universe in which we live.

But that didn't stop Friedmann speculating. In a book, World As Space And Time, published in 1923, he wrote: 'It is useless, due to the lack of reliable astronomical data, to cite any numbers that describe the life of our Universe. Yet if we compute, for the sake of curiosity, the time when the Universe was created from a point to its present state, ie, time that has passed from the 'creation of the world,' then we get a number equal to tens of billions of usual years.' This is pretty close to the accepted modern value, 13.8 billion years, but nobody took any notice at the time.



A map of the Cosmic Microwave Background - the afterglow radiation of the Big Bang

### Galaxies or nebulae?

What Friedmann didn't know was that there was already astronomical data that supported his idea. At the Lowell Observatory in America, Vesto Melvin Slipher (always 'VM' to his colleagues) had been studying the light from objects then known as nebulae – spiral 'clouds' of material. There was a debate about whether these were clouds of gas within the Milky Way, perhaps sites of star formation, or much larger objects far beyond the Milky Way – galaxies (as we now call them) in their own right.

To his surprise, Slipher found that the light from these spiral nebulae is 'redshifted', by a large amount. The naive explanation for this was that the objects are moving rapidly away from us, and the redshifts are caused by the Doppler effect. This suggested that they were indeed beyond the Milky Way. But there is another possibility. In the expanding Universe models discovered by Friedmann (but which Slipher knew nothing of), a similar redshift effect is produced by the stretching of space as time passes.

The debate about the nature of the spiral nebulae was resolved in 1924. Edwin Hubble, working at the then-new 100-inch telescope at Mount Wilson

PHOTO: SCIENCE PHOTO LIBRARY X2

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The Universe was born from a single point in time and space, a discovery made possible by identifying the radiation from the Big Bang itself

## > IN A NUTSHELL

How the Universe began was one of the biggest questions facing science. Over the course of the 20th Century, a series of astronomical observations and fortuitous physics experiments finally verified the Big Bang theory.

in California, which was far more powerful than the telescope Slipher had, was able to measure the distance to the Andromeda Nebula (or galaxy) by studying variable stars known as Cepheids within the 'nebula'. This, and measurements of distances to other nebulae, established once and for all that the spirals were indeed galaxies far out into the Universe. The time was ripe for someone to put redshifts and distances together, adding in the equations of the General Theory of Relativity to provide a description of our Universe.

That someone was Georges Lemaître, a Belgian mathematician and astronomer who added two and two to make four. Lemaître, although based in Belgium, had visited Cambridge in England, Harvard, and Mount Wilson. He had met both Slipher and Hubble, and was up to date on all the observations, but completely unaware of Friedmann's work. So when he independently discovered the same solutions to Einstein's equations that Friedmann had found, his interpretation of the equations was based on observations of the real Universe. Putting everything together, and estimating the distances to galaxies by a rule of thumb that fainter galaxies must be further away than brighter galaxies, he discovered that the redshift of a galaxy depends on its distance from us – its 'velocity' is proportional to its distance. But he was aware that this is not a Doppler effect. As he put it in 1927, the redshifts are 'a cosmical effect of the expansion of the Universe'.

This discovery – which really ought to be known as Lemaître's Law – was published in a paper whose title translates

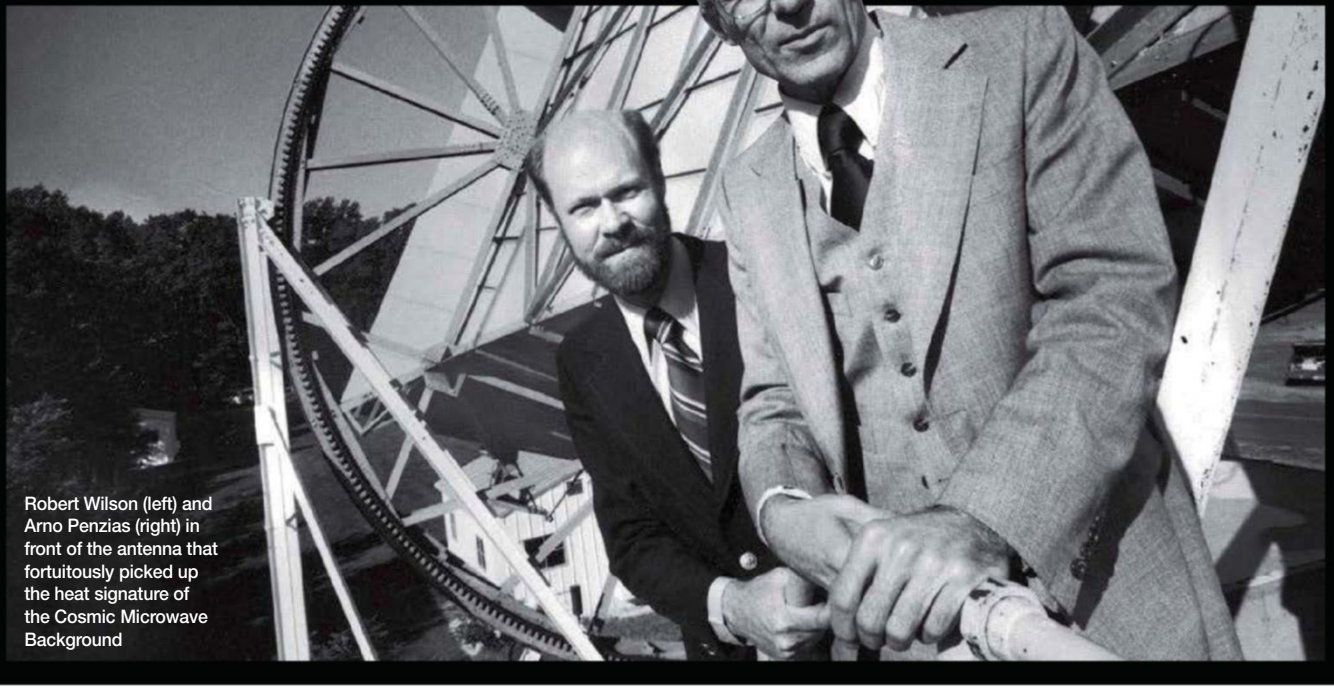
## THE KEY EXPERIMENT

**A baffling find by Penzias and Wilson that the Universe was warmer than it should be at their radio antenna turned out to be a major discovery that would earn them a Nobel Prize**

The horn antenna at Crawford Hill in New Jersey was built for use with satellites, so the shape of it was designed to minimise interference from the ground, and provide the best possible measurement of the strength of radio noise from the sky. The nature of this radiation depends on the temperature of the radiating object. The amplifiers used in the receiver were cooled to 4.2K (-268.8°C) using liquid helium, and Penzias devised a 'cold load', cooled by liquid helium to about 5K, which was used to calibrate the system. By switching the antenna from observations of the cold load to observations of the sky, they could measure the apparent temperature of the Universe (expected to be 0 Kelvin) then subtract out known factors, such as the interference from the atmosphere above.

But in 1964 it soon became clear that the radiation coming from the antenna into the receiver was at least 2K hotter than they could explain. The pair did everything they could think of to remove any sources of interference, including cleaning out the layer of droppings that had accumulated in the antenna horn from a pair of nesting pigeons. Nothing made much difference. The mystery of the 'excess antenna temperature' continued to baffle them throughout 1964.

That is until they realised, with the help of Dicke, Peebles, Roll and Wilkinson at Princeton University, that they were looking at the afterglow radiation of the Big Bang.



Robert Wilson (left) and Arno Penzias (right) in front of the antenna that fortuitously picked up the heat signature of the Cosmic Microwave Background

PHOTO: GETTY X3, CORBIS, SCIENCE PHOTO LIBRARY, NASA

as 'A Homogeneous Universe of Constant Mass and Increasing Radius Accounting for the Radial Velocities of Extra-Galactic Nebulae'. He also worked out the relationship between redshift and distance, coming up with a figure of 575km per second per Megaparsec for what is now known as Hubble's constant (for reasons that will become clear) So a galaxy 1Mpc away is receding at 575km/s; a galaxy at a distance of 2Mpc is receding at 1,150km/s, and so on. But Lemaître's 1927 paper was published in an obscure Belgian journal, and nobody noticed it – even though he sent a copy to the leading British astronomer of the day, Arthur Eddington.

### Hubble in a hurry

Meanwhile, Hubble had been busy. He recruited a more junior astronomer (but the best observer in the world), Milton Humason, to measure redshifts of galaxies, while Hubble measured distances by a variety of techniques. In 1929, Hubble and Humason published a paper based on a study of 24 galaxies, 20 of which had redshifts measured by Slipher, and four with 'new' redshifts obtained by Humason.

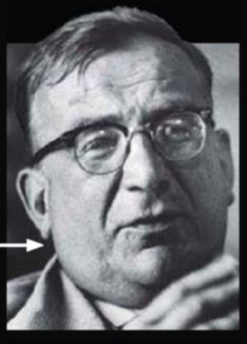
This was enough for Hubble to publish the now-famous discovery of the redshift-distance relationship. It showed that the distance of a galaxy from us is directly proportional to the velocity implied by its redshift. This – exactly what Lemaître had published two years earlier – became known as 'Hubble's Law'. The value of the Hubble constant in the Hubble and Humason paper was 500km/s per Mpc, suspiciously close to Lemaître's value. There was no mention in that paper, though, of either Slipher or Lemaître. Hubble, a notoriously vain and unpleasant self-publicist, did everything he could to take all the credit and glory, and to a large extent succeeded.

This time, the news spread like wild-fire. Lemaître, understandably miffed, wrote to Eddington reminding him of the 1927 paper, and Eddington did everything he could to spread the news of Lemaître's priority, including getting a translation of the paper published in English. Lemaître did eventually get the credit he deserved. But it was Hubble who got the law named after him.

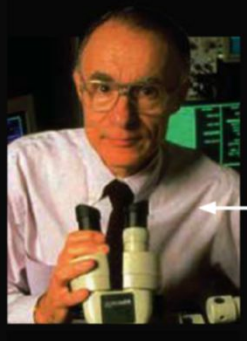
## CAST OF CHARACTERS

It was Lemaître's initial brilliance that enabled others to prove the Big Bang theory

**Georges Lemaître** (1894-1966) was a Belgian astronomer, and also an ordained priest, who worked at Louvain University. He was the first person to suggest that the Universe started from a hot, superdense state, which he called the 'primeval atom'. He discovered the rule now known as 'Hubble's law' two years before Hubble.

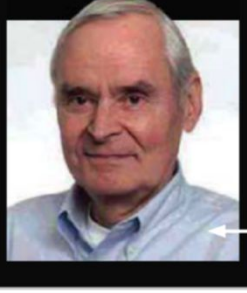


**George Gamow** (1904-1968) was a Russian-born American astronomer, based in Washington, who developed Lemaître's idea and promoted it in the 1940s and 1950s. His students Ralph Alpher and Robert Herman calculated that the radiation from the primeval fireball should fill the Universe at a temperature of a few Kelvin, but the prediction was forgotten.



**Arno Penzias** (1933- ) is a German-born American astronomer who worked at Bell Laboratories. Most of his work dealt with developing instrumentation for radio astronomy and satellite communication but in 1964, working with Robert Wilson, he accidentally discovered the background radiation that Gamow's team had predicted more than a decade earlier.

**Robert Wilson** (1936- ) is another American radio astronomer who worked at Bell Laboratories. As a student he was strongly influenced by Fred Hoyle, and became a supporter of the Steady State model of the Universe. Ironically, he shared the Nobel Prize with Penzias in 1978 for making the discovery that killed off the Steady State model.



**David Wilkinson** (1935-2002) was an American astrophysicist who devoted his career largely to the investigation of the cosmic microwave background radiation after its discovery. Nobody made a greater contribution to the field over the next 30 years, and the Wilkinson Microwave Anisotropy Probe satellite (WMAP) was named in his honour.

## TIMELINE

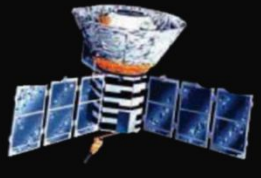
It could be the biggest question of all: how did the Universe begin? It took decades of discovery to answer

**1929** – Edwin Hubble discovers that the distance of a galaxy from us is directly proportional to the velocity implied by its redshift. Lemaître had published this in 1927, but nobody had noticed.

**1931** – Lemaître writes in Nature: 'We could conceive the beginning of the Universe in the form of a unique atom, the atomic weight of which is the total mass of the Universe.'

**1948** – Alpher (pictured) and Herman calculate that the leftover radiation from the primeval fireball should still fill the Universe today, with a temperature of about 5K. This was also published in Nature.

**1964** – Penzias and Wilson discover a weak hiss of radio noise coming from all directions in space. The following year this is explained as the leftover radiation from the Big Bang.



**1989** – Launch of the Cosmic Background Explorer satellite (COBE), which detected tiny irregularities (ripples) in the background radiation, confirming the accuracy of the Big Bang model.

**2001** – Launch of the Wilkinson Microwave Anisotropy Probe (WMAP), which makes precision measurements of the background radiation, pinning the age of the Universe down as 13.8 billion years.

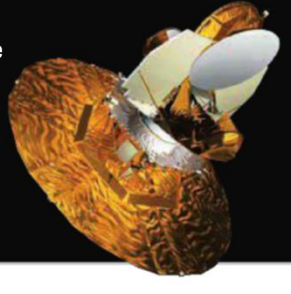


PHOTO: GETTY, SCIENCE PHOTO LIBRARY, NASA X3

Lemaître, though, wasn't finished. Hubble was only interested in using redshifts to measure distances, and never tried to fit them to any cosmological model. Most relativists simply regarded the equations as something to play with, of no relevance to the real world. Lemaître, though, took them at face value and used them to attempt a description of how the Universe began. In 1931, he speculated that the Universe might have begun violently (in 'fireworks') in a very dense state, which expanded dramatically to become the world as we see it today. He developed these ideas in a book published in 1946, and referred to the origin of the Universe either as the 'primeval atom' or the 'cosmic egg'. This inspired the Russian-born American George Gamow to take up the idea and develop it further, with the aid of his colleagues Ralph Alpher and Robert Herman.

Ralph Alpher realised that the heat from Lemaître's 'fireworks' should have filled the Universe with electromagnetic radiation, which would still exist today in the form of cold radio waves. In 1948, he published a paper in Nature concluding that 'the temperature in the Universe at the present time is found to be about 5 Kelvin [–268°C].' Gamow promoted the idea for a time (and now often incorrectly gets the credit for it), but in those days nobody thought that such cosmic background radiation could be detected, and the idea was soon forgotten.

### Big bang quandaries

But there was a problem with the Big Bang idea, as it was being called by the 1950s. The speed with which galaxies are moving apart today tells us how long it has been since they were all squeezed together in Lemaître's cosmic egg. This 'age of the Universe' is related to Hubble's constant – the bigger the constant, the faster the galaxies are separating and the younger the Universe. For a value of 500km/s per Mpc, the Universe would only be about a billion years old – far younger than the known ages of the Sun and stars. This encouraged the rival Steady State model of the Universe, which says that the Universe has always existed and always

## JARGON BUSTER

The cosmic terms you'll need to understand the Big Bang

### COSMOLOGICAL REDSHIFT

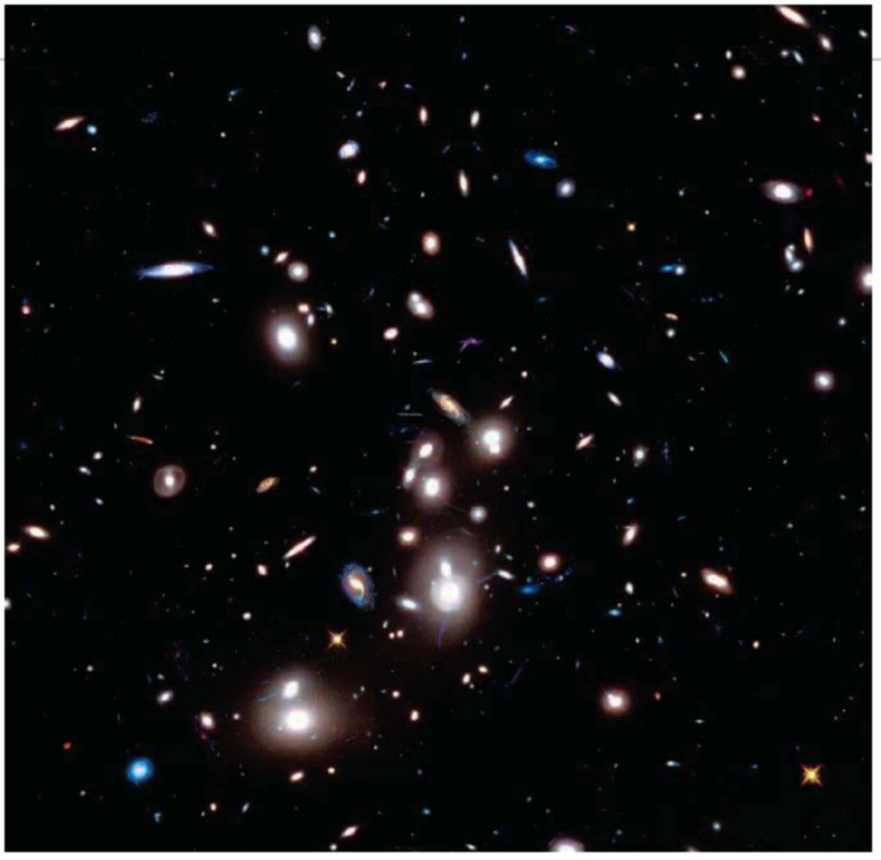
A stretching of light, or other electromagnetic radiation, caused by the stretching of space between the galaxies as a result of the expansion of the Universe. This is not a Doppler effect, because it does not involve motion through space, but is measured in units of velocity. The cosmic background radiation is light from the Big Bang with a redshift of 1,000.

### HUBBLE'S LAW

Actually first discovered by Lemaître, the law says that the redshift 'velocity' of a galaxy is proportional to its distance. So a galaxy twice as far away is receding twice as fast, and so on. This does not mean we are at the centre of the Universe, however. The law works the same way whichever galaxy you observe from.

### MICROWAVES

Microwaves are radio waves with wavelengths in the range from 1-30cm. In astronomy they're used to study the background radiation left over from the Big Bang, and in the study of interstellar molecules. On Earth they're used in microwave ovens, radar and telecommunications. The Universe is a microwave oven with a temperature of -270.3°C.



The light from Pandora's Cluster – a group of galaxies in the deepest realms of the observable Universe – has been shifted to the red end of the spectrum due to the expansion of the Universe

expands but that new atoms pop into existence as space stretches to make new galaxies which fill the gaps.

The Big Bang idea gradually became more respectable as better telescopes and improved observations showed that the Hubble constant is much smaller than Lemaître and Hubble had estimated – less than 100km/s per Mpc. Then came the decisive moment.

In 1964, Arno Penzias and Robert Wilson were adapting a radio telescope built to test satellite communications for radio astronomy. The telescope, at Crawford Hill in New Jersey, belonged to the Bell telephone company. Before it could be used for astronomy, it had to be calibrated. Penzias and Wilson found that it was plagued by what seemed to be interference. A weak hiss of radio noise showed up in the instruments no matter which part of the sky they pointed the telescope to. They were utterly baffled. Then, in December 1964, Penzias happened to mention the problem to another radio astronomer, Bernard Burke, who said that he knew of a team at Princeton University (a 30-minute drive away) who might shed some light on the problem.

That team was headed by Jim Peebles and Robert Dicke, with two junior colleagues, Peter Roll and David Wilkinson. Dicke had independently come up with the same idea as Ralph Alpher, but had gone one step further by initiating a project to build a telescope to look for the predicted radiation. The telescope was nearly complete when Penzias and Wilson got in touch. The two teams put their heads together, and quickly established that what Penzias and Wilson had found could indeed be the 'echo of the Big Bang'. They produced a pair of papers in the July 1965 issue of the Astrophysical Journal. Dicke, Peebles, Roll and Wilkinson came first, setting out the theory of leftover radiation from a hot early Universe. That paper was followed by Penzias and Wilson with 'A Measurement of Excess Antenna Temperature at 4,080 Mc/s', making no mention of the possible significance of the discovery except for the sentence 'A possible explanation for the observed excess noise temperature is the one given by Dicke, Peebles, Roll and Wilkinson in a companion letter in this issue.' It was the proof that there really was a Big Bang.

In the following decades, three key satellites probed details of the Big Bang. The first was COBE, launched in 1989, which detected ripples in the background radiation produced by the seeds on which galaxies grew. The Big Bang theory had triumphed.

**JOHN GRIBBIN** is a visiting fellow in astronomy at the University of Sussex, and author of Science: A History

# WHY WE LOVE ALCOHOL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ILLUSTRATOR: MAGICTORCH

We all like a drink sometimes, but so do apes, flies and many other animals. Biologist **Robert Dudley** asks whether our thirst for booze can be put down to evolution

Primates like this western lowland gorilla developed stereoscopic, colour vision and a keen sense of smell to detect fermenting fruit in the jungle

Walk into any pub or restaurant, and you will find people enjoying alcoholic beverages. Or perhaps not enjoying them, if they have had too much and then proceed to stagger into the street and rudely vomit. What is it about the alcohol molecule that can either inspire us via cuisine and social culture, or alternatively destroy us through liver cirrhosis and drink driving?

A new evolutionary perspective, termed the 'drunken monkey hypothesis', links the psychoactive effects of alcohol to our ancestral exposure to the molecule as fruit-eating primates. Fruit contains sugars that form the basis of the diet for thousands of species of birds and mammals. And particularly in the moist tropics, where air temperatures are high and yeasts abound, these fruits partially ferment and contain alcohol in addition to their carbohydrate rewards. Animals consuming them enjoy a tipple as well.

This isn't necessarily a bad thing. Over long distances, the smell of alcohol vapour reliably points to the presence of calories for animals to find the fruit. And once there, alcohol can stimulate the appetite, promoting faster rates of consumption. This is well known to us today as the

Fruit flies love a tipple - they use alcohol vapour to detect ripe fruit; they're helping us understand the mechanisms behind addiction

PHOTO: FIONA ROGERS/NATUREPL.COM, ALAMY, THINKSTOCK, ALEX HYDE/NATUREPL.COM, SOLVIN ZANKL/NATUREPL.COM, ANNETTE ZITZMANN, OTTO PLANTEMA/FLPA, PHOTO RESEARCHERS/FLPA

**"Today, we are clearly demand- and not supply-limited in our consumption of alcohol"**

apéritif effect. Our behavioural responses to alcohol may therefore have been moulded over evolutionary timescales. Although usually beneficial, some aspects of our relationship with alcohol can also drift into patterns of excessive consumption and abuse. This too may be an unfortunate but predictable product of evolution.

### A poison that heals?

Many compounds that we eat are essential for living, but are also unhealthy or even toxic at sufficiently high levels. Obvious examples include fats and carbohydrates, basic fuels of life that nonetheless can result in obesity when eaten in excess. Similarly, many vitamins and minerals are necessary components of the diet, but only in very small quantities; excessive consumption can be dangerous. This effect has been termed hormesis by toxicologists, whereby moderate levels will maximise benefits and minimise costs of exposure to otherwise potentially toxic compounds. Abstention can be equally unhealthy. Can alcohol consumption be viewed similarly?

The scientists would say yes. Starting in the 1970s with the work of Art Klatsky at Kaiser Permanente in Oakland, California, numerous studies since have demonstrated substantial benefits to human health and overall life-span from moderate levels of alcohol (one to three typical drinks a day), relative to either abstention or higher levels of drink. Most, but not all, of these effects come from reduced cardiovascular risk. And remarkably, similar outcomes can be found with adult fruit flies exposed to alcohol vapours at different concentrations. Their life-span is highest at intermediate levels of exposure. Fruit flies in nature follow alcohol plumes upwind to find ripe and fermenting fruit upon which they lay their eggs, and within which the larvae develop. Exposure to booze is therefore a natural feature of their biology. But what exactly is the historical background for alcohol consumption in primates, and more importantly, in the lineage leading to modern humans?

### Drunk monkeys

Humans eat from a wide range of food items, but until recently we were much less catholic in our diet. As great apes, we are derived from a predominantly fruit-eating lineage of primates. For example, our closest living relatives (the gibbons, orangutans, gorillas, and chimps), are all strongly dependent on large, sugar-rich fruits. The only exception are the highland gorillas (as popularised by Dian Fossey and her book Gorillas In the Mist), which eat herbaceous vegetation given the absence of large fruits at elevations in the tropics exceeding 1,500m. Primates actually diversified in the lowland tropics as fruit eaters about 45 million years ago. Various sensory adaptations, including stereoscopic (3D) and trichromatic (colour) vision, enable primates to see ripe and colourful fruit, which can otherwise be hard to find at distance in the green and cluttered forest canopy.

Olfactory (smell) sensitivity of monkeys to various kinds of alcohol has also been shown to be high. "Spider monkeys are a perfect species with which to test the drunken monkey hypothesis," writes anthropologist Dr Christina Campbell at California State University, Northridge. "They are highly frugivorous [fruit-eating] and have been shown to be extremely sensitive in their ability to discern low levels of ethanol in taste experiments."

Her work in Panama assesses alcohol levels in wild fruits preferred by monkeys, and relates them to the secondary products of alcohol found in both urine and hair samples. And it may not just be fruit that's supplying primates and other animals with booze. Biologist Frank Wiens spent years in the Malaysian rainforest studying the reactions of slow lorises, tree shrews, and other mammals to the nectar within flowers of a large palm tree. The nectar was found to be consistently fermenting and providing alcohol rewards. Many species of birds, like hummingbirds and sunbirds, and of course numerous insects, also feed on nectar full-time. So it's important to understand that a natural exposure

Spider monkeys have a particularly fine taste for alcohol

## ALCOHOL-LOVING ANIMALS

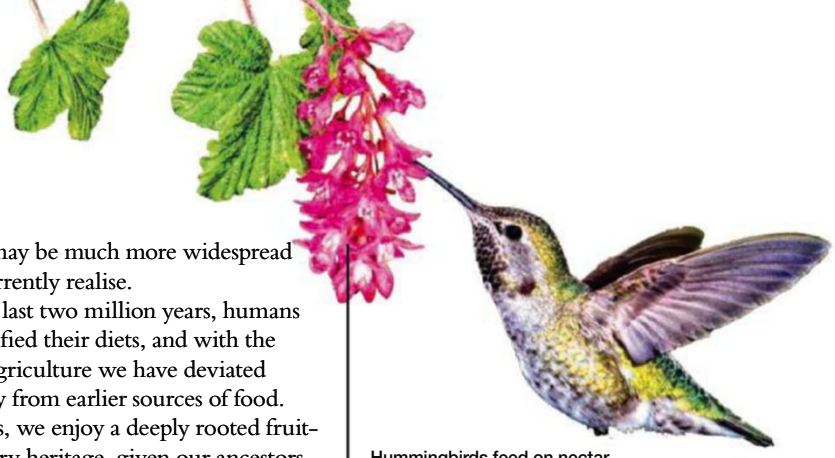
**PEN-TAILED TREESHREWS**
These close relatives of the primates lap up fermenting nectar all night long from blossoms of the large bertram palm. The Malaysian animals never seem to get drunk, but hair samples reveal the presence of a secondary product of alcohol (ethyl glucuronide), which otherwise turns up only in human alcoholics.

**FRUIT-FEEDING BUTTERFLIES**
Particularly in the tropics, many butterflies visit fallen and fermenting fruits rather than flowers to obtain nourishment. Reports of inebriated butterflies, and the use of gloopy mixtures of molasses and beer to attract moths in the temperate zone, suggest the important behavioural roles of alcohol.

**CEDAR WAXWINGS**
The Cedar Waxwing and other fruit-eating birds in the temperate zone occasionally turn up drunk on the ground and unable to fly. One report of mass mortality in Cedar Waxwings revealed dangerously high levels of alcohol in the liver, consistent with lethal inebriation.

**FRUIT FLIES**
Female fruit flies fly upwind when smelling alcohol vapour and look for fermenting fruit upon which to lay their eggs. The larvae are equipped to be able to metabolise different concentrations of alcohol. What's more, male fruit flies rejected by females prefer alcohol-enhanced food.

**VERVET MONKEYS**
On the Caribbean island of St Kitts the African monkeys steal tourist drinks on the beach and wreak mayhem among the sunbathing public. In controlled experiments with captive populations, some individuals avoid alcohol whereas others binge drink, leading to premature death. Most monkeys tend, however, to drink moderately.



Hummingbirds feed on nectar, which ferments to alcohol

to alcohol may be much more widespread than we currently realise.

Over the last two million years, humans have diversified their diets, and with the origins of agriculture we have deviated dramatically from earlier sources of food. Nonetheless, we enjoy a deeply rooted fruit-eating dietary heritage, given our ancestors were aping about in the forest. And whoever was eating ripe fruit was also consuming alcohol, albeit in small amounts. In parallel with the first Neolithic experiments in plant cultivation, the intentional fermentation of fruits and grains may also have provided psychoactive impetus to master the skill of farming. The invention of distillation, a chemical process dating back only several thousand years, then provided the possibility to consume high-concentration alcohol in pure liquid form. Unfortunately, behaviours and nutritional strategies that once worked safely in the jungle, where fruits contain only small amounts of alcohol, can be dangerous when we forage in the supermarket for booze.

Today, we are clearly demand- and not supply-limited in our consumption of alcohol. And for the unfortunate few, this lust for drink can lead to alcoholism. But recognition of our ancestral dietary exposure to the molecule suggests that our current responses may be based on behaviours that were once advantageous. The rapid identification and consumption of alcohol-containing fruits, so useful in the rainforest, can become a problem in the modern world. Similar arguments have been given as a cause of diseases like obesity and diabetes, with the essentially unlimited availability of cheap sugars and fats. These so-called diseases of nutritional excess derive from a mismatch between ancient and modern food environments. Could alcoholism have similar origins?

### Drink and Humans

An intriguing hint to this effect is provided by genetic differences among modern humans in the ability to metabolise alcohol, and correspondingly in the tendency to drink. In East Asia, many individuals possess a slow-acting version of the enzyme (ALDH) that serves in alcohol metabolism. If they do drink, toxic intermediate products build up and make them sick, so they tend not to drink at all. We don't yet know the selective forces that led to such a varied geographical distribution of this characteristic. Variation

**"We enjoy a deeply rooted fruit-eating dietary heritage, given our ancestors were aping about in the forest"**

## UNRAVELLING ADDICTION

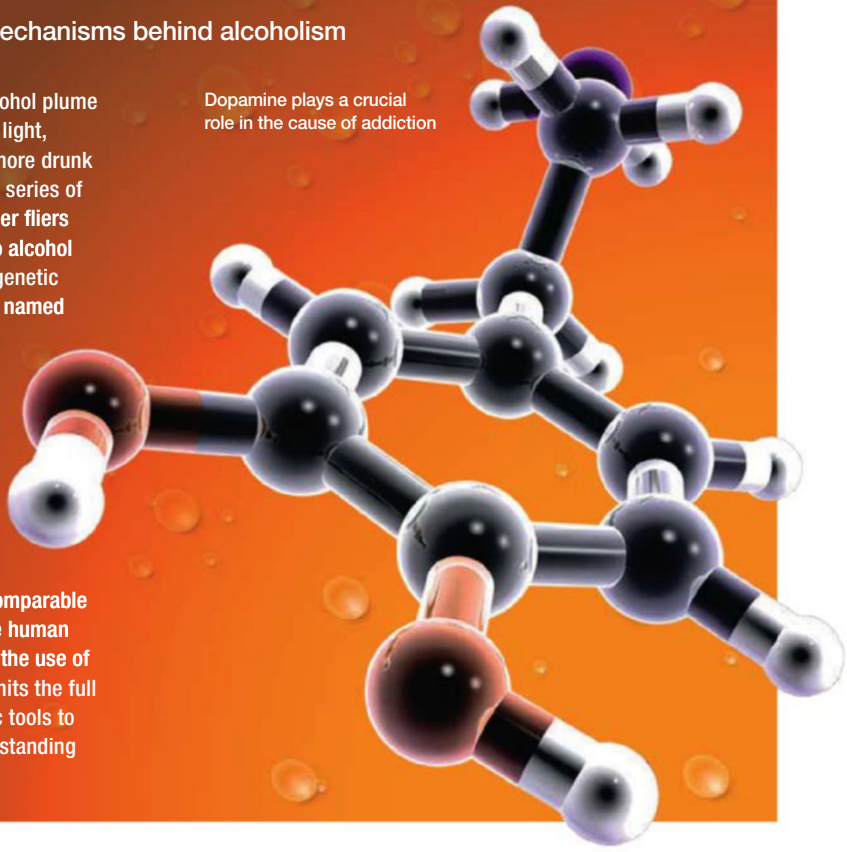
Drunk fruit flies are shedding light on the cellular mechanisms behind alcoholism

Addiction to alcohol poses major health challenges, but it's obviously not possible to experiment with humans to understand the cellular changes underlying the disease. However, fruit flies present a useful model with which to study various physiological mechanisms that come into play during addiction.

Alcohol influences many different features of the nervous system in all animals. However, a number of cell signalling pathways within the neurones of fruit flies and rodents are activated similarly during alcohol exposure. Many addictions involve changes to the neurotransmitter dopamine, which acts in motivational and reward neural circuitry. In fruit flies, a number of genetic mutants have been identified that influence both susceptibility to alcohol and the ability to degrade it once exposed.

Flies placed within an alcohol plume will fly upwards toward a light, becoming progressively more drunk and then settling out on a series of stacked funnels. The higher fliers are thus more resistant to alcohol and can be collected for genetic analysis. The wonderfully named 'happy hour mutant', for example, handles booze fairly well, whereas 'cheap date' is particularly prone to inebriation. The 'hangover mutation' provides for greater short-term tolerance.

We don't yet know if comparable genetic variants influence human responses to alcohol, but the use of fruit flies as a model permits the full line-up of modern genetic tools to be applied towards understanding addictive behaviour.



Dopamine plays a crucial role in the cause of addiction

PHOTO: GETTY X3, SCIENCE PHOTO LIBRARY

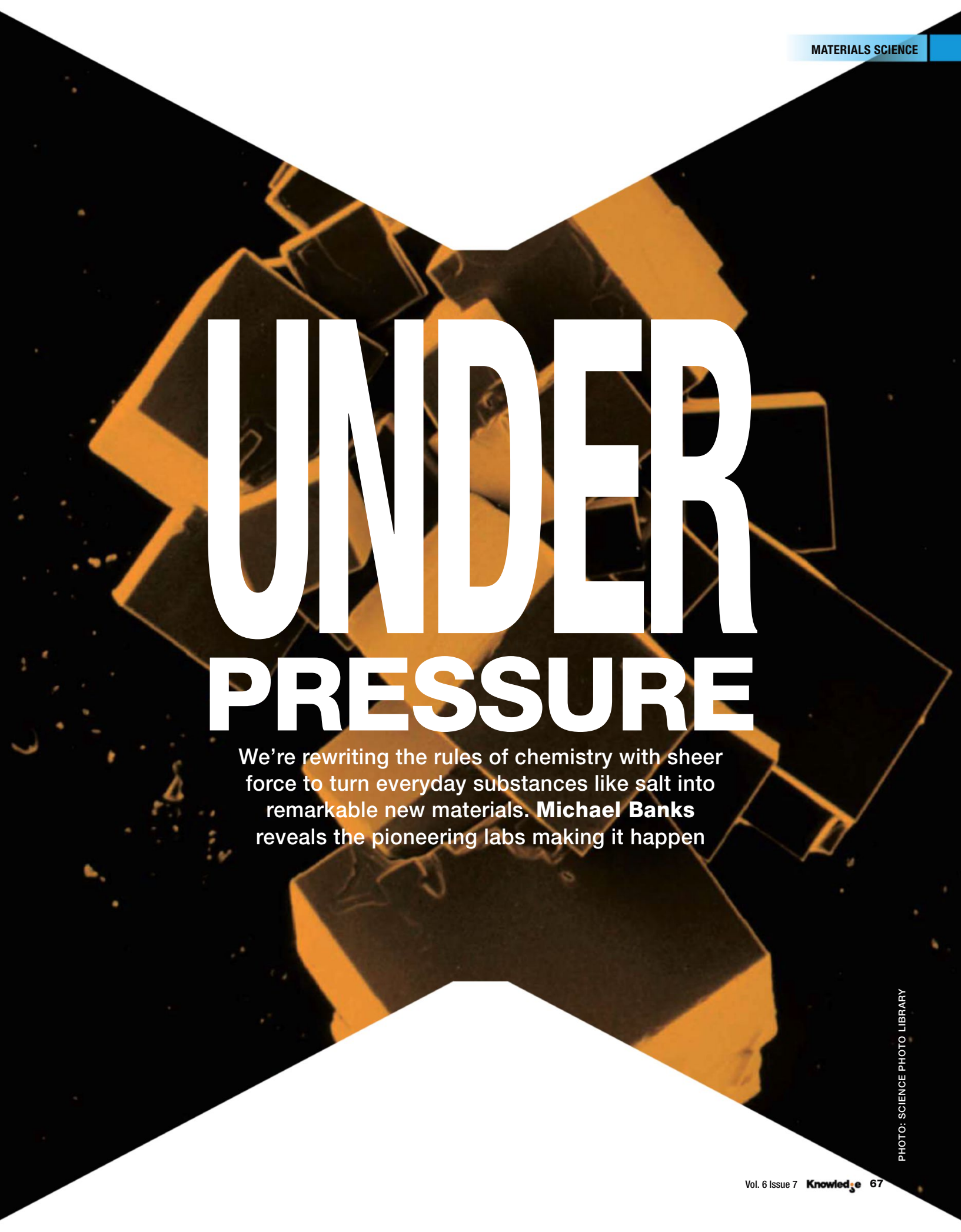
Fermentation takes place at a whisky distillery; the process enabled our ancestors to drink higher concentrations of alcohol in liquid form


With an abundance of alcohol available in the modern world, our ancient genetic predisposition to it can become an addiction

in the capacity to metabolise alcohol has also been characterised among different species of fruit flies. So addiction to alcohol, in other words, may in part reflect selective forces associated with past exposure. Alcoholism has long been known to run in families and to be partially heritable, which is consistent with this evolutionary scenario.

Nonetheless, health benefits can also derive from low-level drinking, so we have to be careful in any assessment of the optimal levels of alcohol consumption. Worldwide, most people do indeed drink moderately, whereas a substantial fraction of the global population is also reported, for either genetic or cultural reasons, to abstain from booze. The American comedian Henny Youngman once proclaimed: "When I read about the evils of drinking, I gave up reading." So the next time you have a pint, or three, think about the complex ecological interactions linking tropical fruits, fermenting yeasts, and primates. Your inner alcohol-loving beast may be closer than you realise.

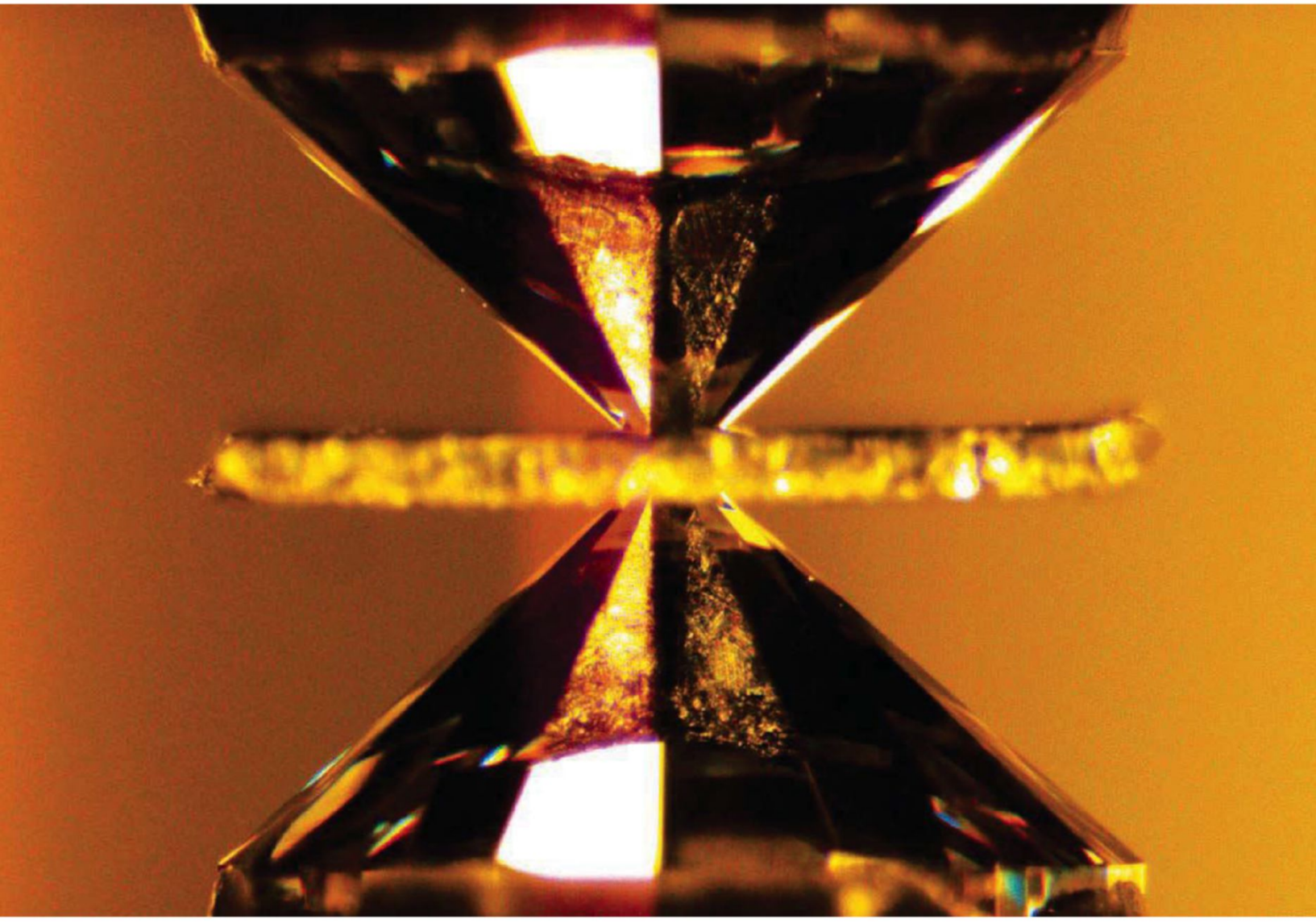
**ROBERT DUDLEY** is Professor of Integrative Biology at the University of California, Berkeley, and author of *The Drunken Monkey: Why We Drink And Abuse Alcohol*



# UNDER PRESSURE

We're rewriting the rules of chemistry with sheer force to turn everyday substances like salt into remarkable new materials. **Michael Banks** reveals the pioneering labs making it happen

PHOTO: SCIENCE PHOTO LIBRARY



Salt is vital for human life. In our bodies this common ingredient regulates the exchange of water between cells. Made up of sodium and chlorine, it plays a key function in the heart, nerve impulses, and the digestion of body-building proteins. Given salt's abundance in nature and how much we eat every day, you might think that we know almost everything there is to find out about the material that has the chemical formula NaCl. But you'd be wrong.

It was commonly thought that NaCl was the only compound that could be created out of its constituent parts of sodium (Na) and chlorine (Cl). The laws of chemistry reflect that compounds tend to form from the strongest bonding possible. For example, in its chemical make-up, sodium has one electron that it wants to lose – having a charge of +1 – while chlorine has a space for an electron (its charge is –1). So sodium happily gives away an electron while chlorine happily takes it. The result is a compound that's neutral in charge and therefore chemically stable, meaning that it cannot decompose back into the individual elements or into any other compounds. At least that's what we thought until now.

## Chemistry reworked

Last year, scientists in China, Russia and the US put tiny crystals of salt under huge pressures – a burden an order of magnitude greater than the pressure at the bottom of the ocean (see 'Feeling the squeeze', p53). What they found was totally unexpected: the material began to form so-called 'forbidden compounds' – ones that experimentalists thought did not even exist. "This work will change the way chemistry is taught and used," says Professor Artem Oganov from the State University of New York, a lead author of the story.

Oganov and colleagues found that when they put salt under a pressure of around 20 gigapascals (GPa – the unit used to measure pressure), or about 200,000 times the pressure of the air, together with a little bit of additional sodium and chlorine, it could

Salt's (NaCl) structure, its 'unit cell', is a basic cube shape, which contains the sodium and chlorine ions

Above: Professor Artem Oganov and his colleagues have managed to turn salt into a variety of exotic materials using high pressures

## "This work will change the way chemistry is taught and used"

Prof Artem Oganov from the State University of New York

Left: the two diamonds of a diamond anvil cell are used to apply extreme pressure

form compounds such as NaCl3 and Na3Cl. These compounds don't have a neutral charge and are thought to have net charges of –2 and +2, respectively – forbidden under the standard rules of chemistry.

Although scientists are not exactly sure why these compounds form, only knowing that the reaction occurs over a couple of seconds, they suggest that the laws of chemistry seem to change under high pressures. "Our work shows the existence of a whole new class of compounds, previously overlooked by chemists," says Oganov. "There is clearly a lot that chemists still need to learn about chemical bonding and rules determining the stability of compounds, so we need more general rules than the ones that exist today."

Indeed, some interesting structures emerge as a result. One product of putting salt under high pressure is Na3Cl. Normal salt is a very bad conductor of electricity. But this new compound is made up of alternating layers of NaCl and pure sodium. The atom-thick sheet of sodium is very similar to the two-dimensional structure of graphene, and could make for a very good conductor of electricity at room temperature. Graphene, the so-called 'wonder material', which is currently finding a myriad of applications, could have new competitors.

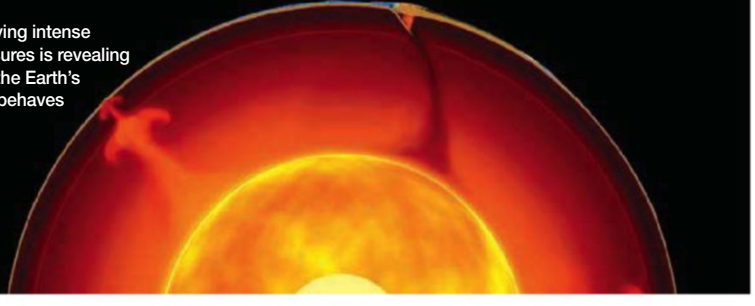
Although physicist Alex Goncharov from the Carnegie Institution of Science, Washington, adds that while there might not be any immediate applications for these specific compounds, given that they are only stable while under pressure, the work opens up the possibility of creating new compounds that could exist at standard air pressure. "The reason we are so excited about this is that we found an example of a very simple system that forms

## PROBING THE CORE OF THE EARTH

### Studies of materials under enormous pressures is helping us paint a picture of the centre of the planet

One of the biggest areas of high-pressure research is creating conditions in the lab that exist at the very centre of planets. Researchers can put iron and its alloys under pressures of around 300GPa – similar to that in the Earth's inner core. They can then test the temperatures that the materials melt, their crystal structure and their density. These findings can then be compared with the properties of the core, which we know about from the way seismic waves pass through it. This enables scienists to tweak the compositions of the materials they're studying to match them up and better understand what the Earth's core is made of. "It helps us understand the chemistry of the Earth, its various temperatures, the details of how it formed," says Earth scientist Oliver Lord from Bristol University.

Andrew Jephcoat at the University of Oxford has also been using pressure to study the Earth's core. He studies how helium can escape from molten iron metal alloys and silicon compounds that were present in the formation of the Earth. Understanding that helium can break up and escape from the alloys tells us that the Earth's core could still hold plenty of the helium isotope $^3$He.



Studying intense pressures is revealing how the Earth's core behaves

PHOTO: STEVE JACOBSON, SCIENCE PHOTO LIBRARY X2

totally unusual compounds," he says. Other compounds the group have discovered so far include KCl3 and CsF2 – compounds containing potassium (K), chlorine, caesium (Cs) and fluorine (F). In contrast with NaCl3 and Na3Cl, they are stable at normal air pressures. They could have applications in storing toxic gases like fluorine and chlorine at low temperatures, since when they are heated slightly they decompose to release the held gas.

What's just as remarkable as the new chemicals being created, is how simple it is to make them. The only thing needed to open the gates to this new chemical playground is a bit of pressure. Well, a lot of it.

## "There is clearly a lot that chemists still need to learn about chemical bonding"

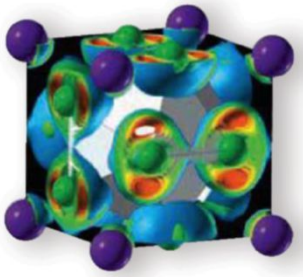
Prof Artem Oganov from the State University of New York

### Elephants on heels

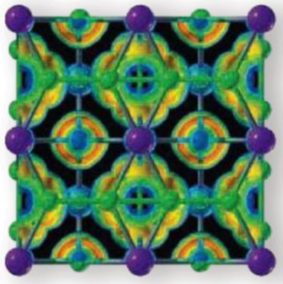
Pressure is a measure of how much something is stressed by applying a continuous physical force on an object by something in contact with it – pressure being the force applied over the contact area. Imagine an adult male elephant weighing around 5,500kg. Its weight will exert a force on the ground. If that force is spread over a large area (say the elephant was lying down) then the pressure would be relatively small. But if the elephant managed to stand on a single stiletto heel (with a square tip with sides of 0.4mm) then the pressure would be huge. Indeed, if you had around 650 elephants all stood on each other's backs on this one stiletto heel it would be equal to the pressure inside the Earth's core.

While scientists don't usually have access to 650 elephants in the lab, they do have diamonds – one of the hardest materials known – to do all the squeezing. Scientists have been doing this since the late 1950s, following the invention of the diamond anvil cell at the US National Bureau of Standards (now known as the National Institute of Standards and Technology). Diamond anvil cells consist of opposing, specially-cut diamonds around a millimetre wide and weighing around 0.2 carats (40mg). The tips of the diamonds are cut and are extremely smooth and finely aligned so that they encase the sample with identical and opposing force. Believe it or not, generating pressure is as simple as tightening bolts connected to the two sides of the cell with a common Allen wrench tool. The cells put a pressure of around 300GPa on a sample – similar to that found in the core of the Earth.

Crystals, like NaCl, are made up of an infinitely repeating array of 3D 'boxes', known as unit cells. For example, salt's unit cell is a basic cube shape, which contains the sodium and chlorine ions. What happens when pressure is applied to a material is



The structure of the compound NaCL3, which is formed by applying pressure to salt with a diamond anvil cell



The extreme material NaCL3 has a single-atom thick layer of sodium, which could prove to be an excellent conductor of electricity

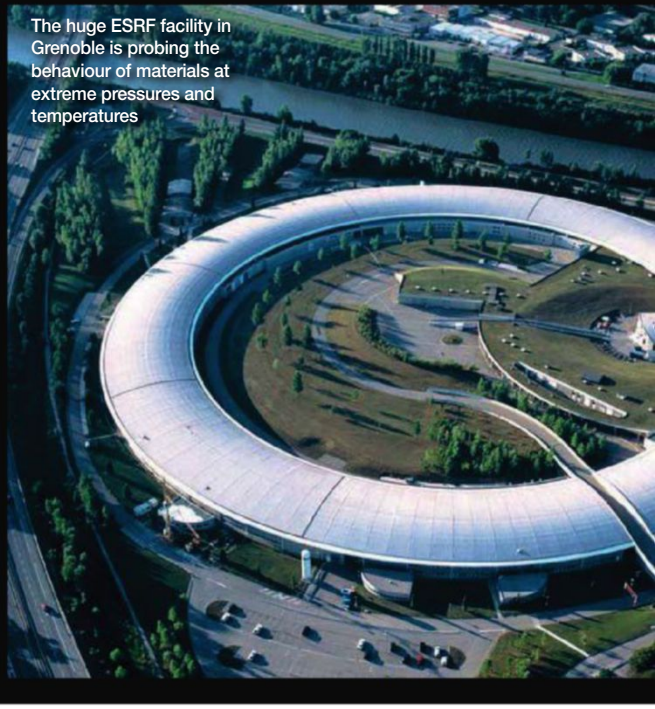
## PUTTING PRESSURE UNDER THE MICROSCOPE

**At a huge facility in France, materials under enormous pressure can be blasted with X-rays so that we can examine their behaviour**

One of the biggest facilities in the world that can produce high-intensity X-rays, enabling scientists to peer into the structure of a whole range of different materials, is the European Synchrotron Radiation Facility (ESRF) in Grenoble, France. To do this, the ESRF accelerates electrons in a 270m diameter storage ring and as the subatomic particles travel in a circle they produce X-rays, which are sent down 40 'beamlines'. Researchers use these to carry out a range of experiments in fields such as physics, medicine and archaeology. Given how powerful the ESRF is, the samples that are used can be 10,000 times smaller than those used in university labs.

In May 2012, the ESRF opened a new beamline with a speciality to study – in real-time – the behaviour of materials at extreme pressures and temperatures. Called ID24, the beamline cost €180m to build and lets researchers shine X-rays into materials that have been squeezed using diamond anvil cells. The materials under study can also be heated up to 10,000°C with short, intense laser pulses.

With such intense pressure and temperatures, the experiment can be used to test materials present in the Earth's liquid iron core – 2,900km beneath the surface – as well as what it is like inside large planets like Jupiter.

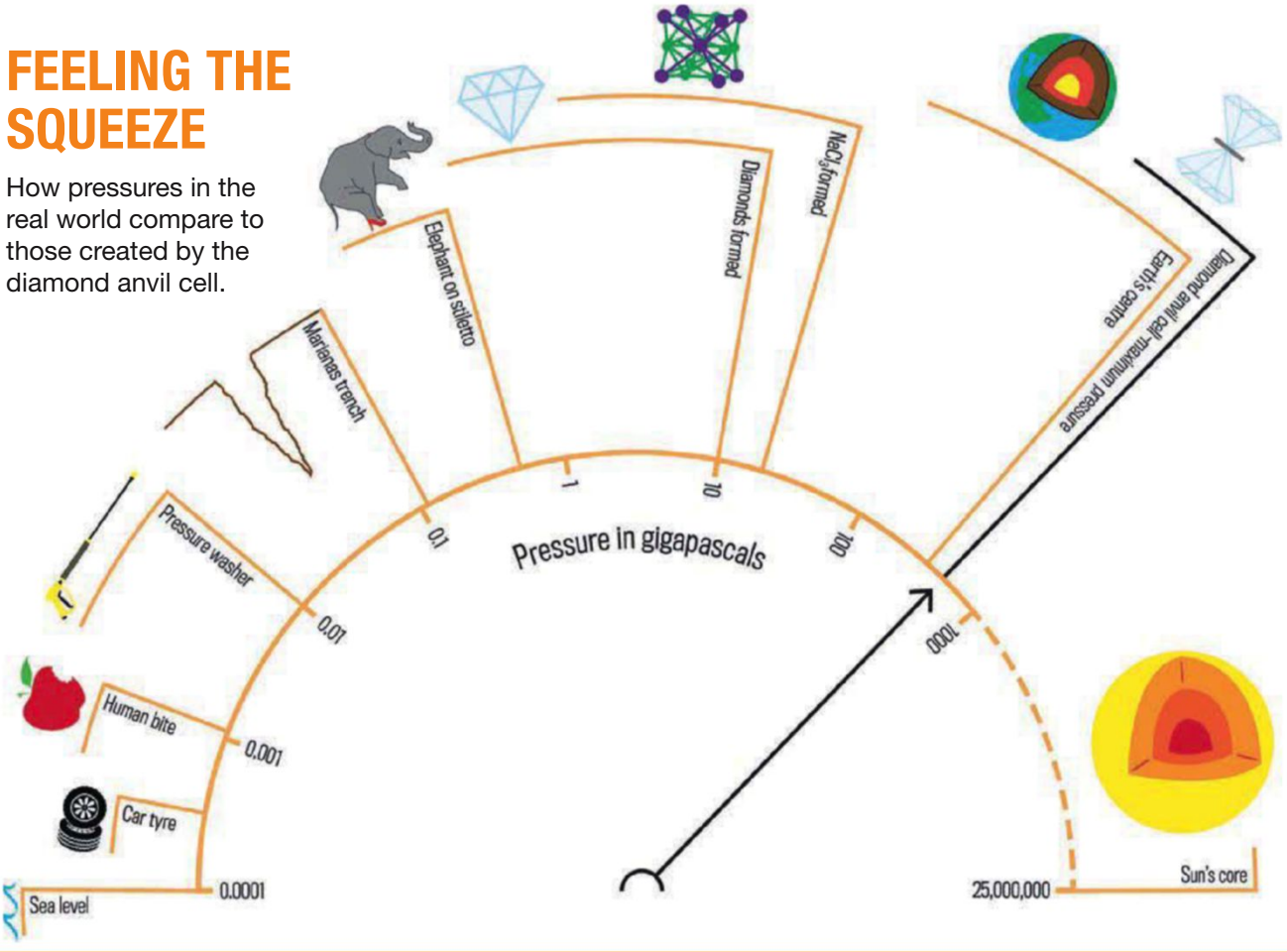


The huge ESRF facility in Grenoble is probing the behaviour of materials at extreme pressures and temperatures

PHOTO: DENIS MOREL/ESRF, ARTEM R OGANOV/WEIWEI ZHANG

## FEELING THE SQUEEZE

How pressures in the real world compare to those created by the diamond anvil cell.




that it squeezes the structure, slowly decreasing the distances between the atoms in the unit cell. The advantage of using diamonds is that they are transparent, meaning that X-rays can then be used to measure the structure of the material and how it changes under pressure without the diamond affecting the signal from the sample (see 'Putting pressure under the microscope, left).

Using diamond anvil cells, researchers can study materials under pressure at different temperatures. Andrew Jephcoat, a physicist at the University of Oxford, is using pressure to explore how hydrogen (chemical symbol H) forms unusual, weakly-bound compounds with other gases such as krypton (chemical symbol Kr) and xenon. This has led them to discover a new range of strange compounds such as Kr(H2)4. "These materials are of interest because they reveal the complexity of bonding possible and they help explain how hydrogen itself may behave at extreme pressure," says Jephcoat. He adds that the work could be used to design new materials for use in hydrogen storage. This is a key technology for fuel cells that could be used in cars, for example, since it converts the chemical energy from a fuel into electricity through a chemical reaction with oxygen.

Another hotbed of research is in superconductivity – materials that allow for the flow of electrons without any resistance, such as magnesium diobride (MgB2). Most superconductors need to be cooled down to –200°C before the effect kicks in, but it would be a boon for power distribution if a room-temperature superconductor could be found. By applying pressure to these compounds, it can either increase the temperature at which they become superconducting or can even make a compound that isn't superconducting at ambient pressure suddenly become so.

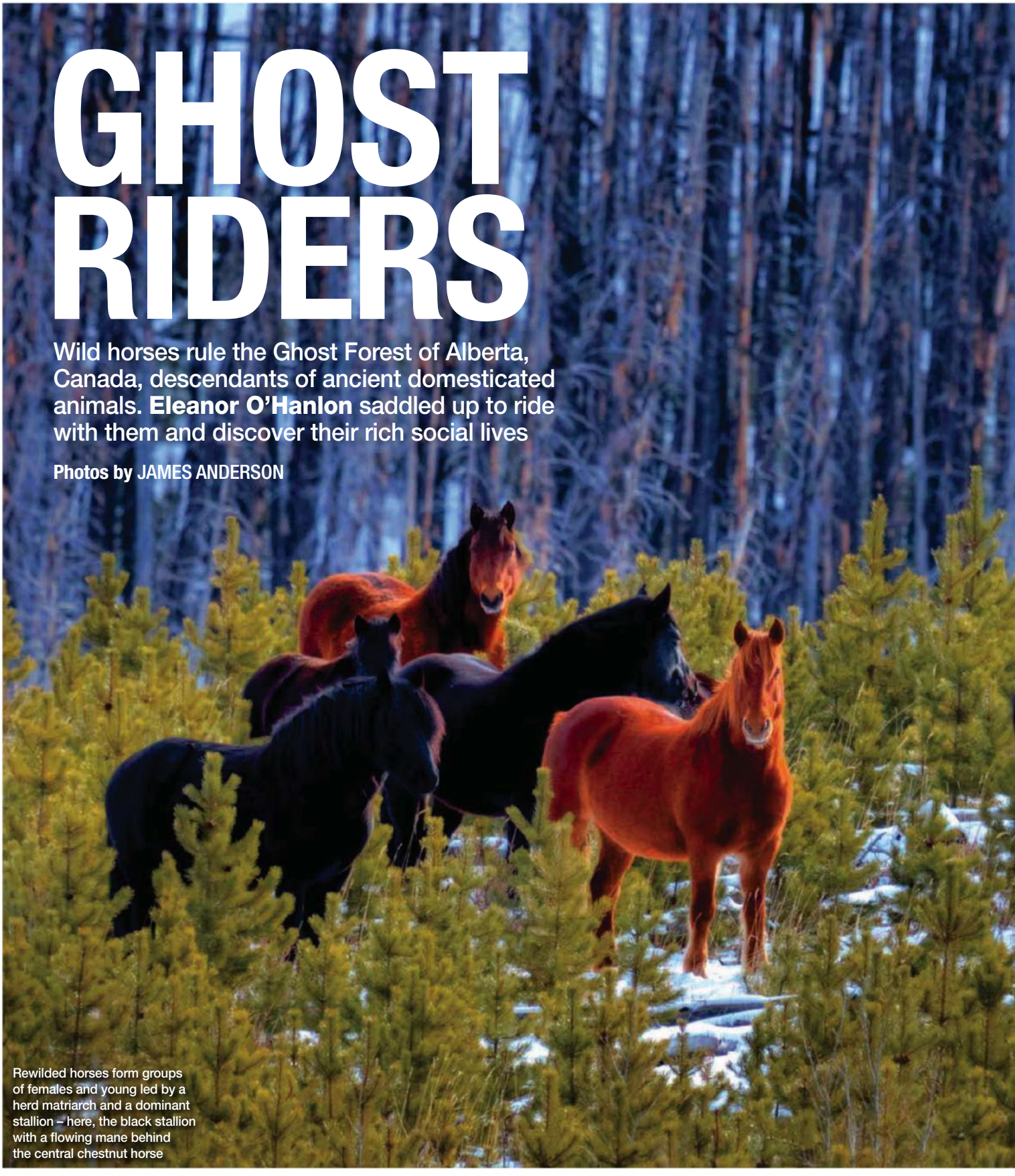
Indeed, Oganov, together with Weiwei Zhang at New York State, have used their crystal structure prediction program – called USPEX – to calculate that a whole range of exotic materials should exist, even at normal ambient conditions. It will keep experimentalists busy for some years to come in attempting to create and make uses for them. "This is only the beginning," Oganov declares.

**MICHAEL BANKS** is news editor of *Physics World* and has a PhD in condensed matter physics

# GHOST RIDERS

Wild horses rule the Ghost Forest of Alberta, Canada, descendants of ancient domesticated animals. **Eleanor O'Hanlon** saddled up to ride with them and discover their rich social lives

**Photos by** JAMES ANDERSON



Rewilded horses form groups of females and young led by a herd matriarch and a dominant stallion – here, the black stallion with a flowing mane behind the central chestnut horse

We may see wild horses any time now," Maureen Enns says. At that moment her chestnut mare, Hope, stops suddenly, ears pricked. I halt my gelding, Amigo, and we listen. Nothing stirs in the dappled green shade between the aspens, but Hope has clearly sensed something that we can't.

I hear a breathy 'huuf'. Among wild herds, that audible exhalation is a signal by the lead horse: move. Hope's tension slackens immediately and she walks forward without prompting, her long strides leading us still deeper into the forest. I follow on Amigo as the mare steps surely between beds of sphagnum moss and fallen aspens. We wind through dense stands of spruce and pine, so thickly clad with lichens that the trees glow grey-white among the shadows. They're visible reminders of the name given to this area of mixed marshland, lake and boreal forest on the eastern slopes of the Rocky Mountains in southern Alberta: the Ghost Forest.

"Hope is my teacher in the language of wild horses," Maureen had told me earlier. Raised among wild herds, the mare still responds to their cues. "One day, she stopped suddenly on the trail," Maureen recalls. "I trust her, so I froze, too. Then I saw the black hairs of a horse's tail flick briefly into the light. Wild horses had been there all along, standing very still in the shadows, and Hope

Most foals are born in spring, and stay close to a mare of their family group when moving between feeding grounds

The stallion's 'flehmen' grimace exposes the vomeronasal gland, enhancing the detection of female hormones and, thus, mares in oestrus

was responding to the stallion's signal to the herd – an instruction to freeze."

That moment demonstrated how the wild horses of the Ghost Forest had learned to protect themselves by hiding like deer, standing motionless in the forest where tree trunks break up the animals' outlines. Such adaptations have helped the horses to survive for over 100 years in a habitat where they could avoid human contact, sharing their range instead with wolves, cougars and grizzly bears as well as other herbivores such as deer, moose and elk.

That moment sparked a determination in Maureen to learn more about these remarkable animals. She began to study them on horseback and on foot, installing a network of remote cameras to minimise the disturbance.

A wildlife artist whose work flows from her intense engagement with the natural world, Maureen has spent years in a remote part of Kamchatka, in the Russian Far East. There she raised orphan brown bear cubs, learning how to communicate with the bears directly so that she could live among them without fear. Maureen had believed that living in such wilderness for so long instilled in her an open mind. Yet when she first came into contact with the wild horses, she realised that she saw these free-roaming creatures as domestic animals. "But as I watch the wild herds, I keep seeing things that completely shatter that preconception," she added.

When I first spoke to Maureen, she described the horses' rich social lives, the careful education of youngsters by the adults, the empathy and care she had witnessed among the wild herds. Seven years of study have convinced her that these horses are not simply domestic escapees – they have truly 'rewilded'.

I've loved horses all my life – and thought I knew them – but talking to Maureen exposed my limited understanding. So when she invited me to ride with her among the wild herd, I leapt at the opportunity.

## Mane attraction

We glimpse them first through gaps between the aspens – glossy, dark-brown bodies on the marshland down by the lake. Six stallions are grazing among the sedges, their summer coats gleaming in the sunshine. They are sleek, muscled, fit – in the Darwinian sense, their beauty sculpted by natural selection. In this harsh mountain land, they face predators and winter temperatures plunging below –30°C.

As they approach sexual maturity – at about two years old – young males are driven from the family herd and join other stallions in bachelor bands, remaining with their male peers till they are mature enough to attract a mate and start a family of their own. Bachelor bands have a definite social structure. Young studs may spar playfully, testing one another's strength and determination, but they cluster

Some 800 wild horses are estimated to roam the Alberta foothills of the Rocky Mountains.

around a leader whose authority they recognise.

Isn't it dangerous to ride a mare around wild stallions? "I know from experience that I couldn't be safer," Maureen avers. "These wild stallions have been raised by the herd and taught to respect the mares. They may approach and look, but they won't come near if they're not invited."

We ride on through aspen stands and grassy clearings to a second lake set among sedge meadows, dwarf birch and bog willow. The forested slopes beyond rise to the snow-covered peaks and turrets of the Rockies, filling the horizon.

A family band of mares, foals, colts and fillies grazes at the far end of the lake. The head stallion feeds slightly apart from the group; he is lean, ribs distinct, his black face and sides scored with white scars from battles with other studs eager to claim one of his mares for themselves.

A solitary stallion, a glossy bay, grazes alone some 20m along the shore. The family's patriarch has positioned himself between this potential rival and his family, the mares and foals together behind him. Hidden among the trees, where we can watch without disturbing the horses, we prepare to dismount and tie up our mounts.

### Primal team

As we stand quietly in the shadows, a wolf materialises from the trees. Maureen gasps as the lone, dark-grey predator stalks towards the horses. I focus my binoculars on the black stallion, expecting a tense encounter as he

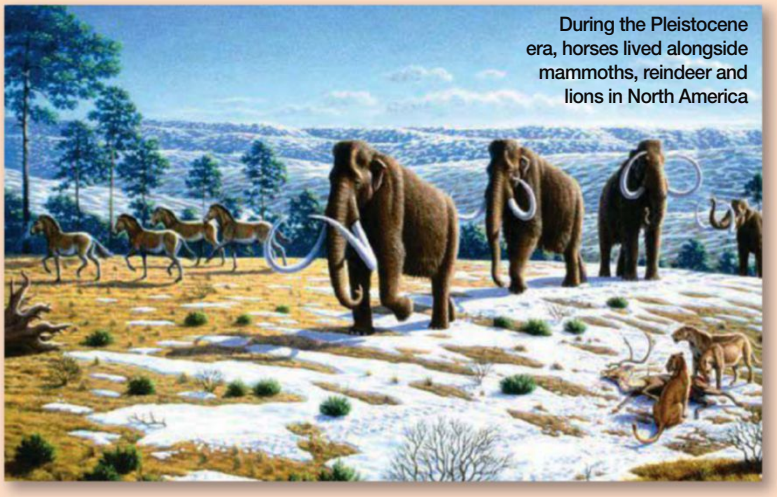
## WILD HORSES IN NORTH AMERICA

Horses evolved in the Americas some four million years ago, migrating into Eurasia where they diversified to produce asses and zebras. American populations fluctuated with climatic shifts, sometimes becoming extinct and being restored by migrations across the land bridge linking Asia with modern-day Alaska. The fossil of an ancestral species Equus lambei, dated to 700,000BC, was found in the Yukon.

During the last glacial period, at least two subspecies of the modern horse Equus caballus grazed North America, alongside a variety of large mammals including the woolly mammoth. They died out about 11,000 years ago.

Horses also ranged throughout Europe, as far south as Iberia, and eastwards into Russia, China and Mongolia. Wild horses even inhabited the harsh tundra regions of northern Siberia, from the Yamal Peninsula to the Kolyma River in the far east.

Today, wild horses are recognised as native European wildlife, making a valuable contribution to ecological diversity and the rewilding of European landscapes. Konik horses, representatives of an ancient breed, have been released in the Netherlands, and the Rewilding Europe project released a group of Andalusian Retuerta horses in Spain in 2012.



During the Pleistocene era, horses lived alongside mammoths, reindeer and lions in North America

MAURICIO ANTON/SCIENCE PHOTO LIBRARY

TOP: The lead stallion nuzzles one of the mares in his harem, maintaining the band's cohesion

LEFT: Colts are driven from their group by the dominant stallion – witness the tuft of tail hairs in the older male's teeth.

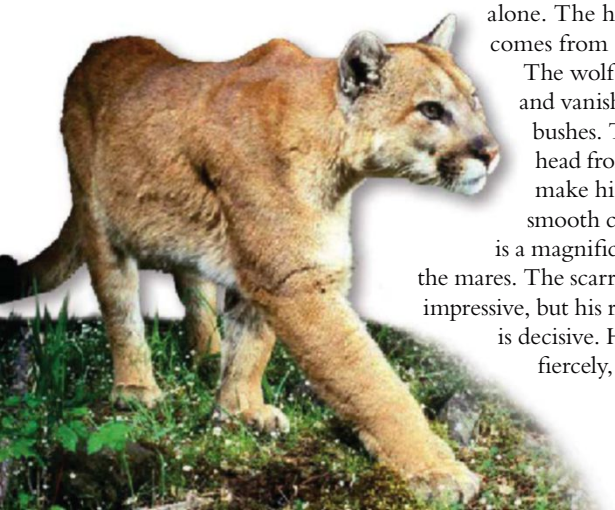
BELOW: Cougars (mountain lions) are the main predators of the rewilded horses in the Ghost Forest

## Encounters between horses and wolves were common across the American plains for hundreds of thousands of years

prepares to defend his family. But the wolf looks as relaxed as if it were out for a gentle afternoon stroll by the lake, and neither stallion – nor the mares or foals – shows any sign of anxiety.

"Incredible," Maureen mutters. "I'm so glad you're seeing this." She's witnessed this kind of easy co-existence between wolves and wild horses before. The wolves den in the forest above the lake, and Maureen has often watched the pups at play. A remote camera even caught images of a young wolf making advances towards a stallion, as though inviting it to come and play.

In seven years of research, Maureen has found horse hair in wolf scat only once, suggesting that the wolves prey mainly on deer, leaving the horse herds, with their strong social bonds and powerful lead stallions, well alone. The horses' main threat, she says, comes from cougars.



The wolf breaks into a buoyant trot, and vanishes into the dwarf birch bushes. The bay stallion raises his head from the sedges and decides to make his move. Visibly aroused, his smooth coat shining, the young stud is a magnificent sight as he paces towards the mares. The scarred black stallion looks less impressive, but his response to this challenge is decisive. He lunges at the bay stud fiercely, forcing him to back off.

Encounters with wolves, like the one I witnessed, were common across the plains and steppe-tundra of North America for hundreds of thousands of years. It's often forgotten that modern horses co-evolved with the landscape, climate and wildlife of North America until about 11,000 years ago when, under pressure from human hunting and the rapidly changing climate, they vanished.

With the disappearance of the land bridge that had connected Alaska with northern Siberia, the continent could no longer be repopulated by horses from Eurasia, as had occurred after several previous extinctions. So horses were absent from the Americas till domesticated animals arrived with the Spanish conquistadors in the early 16th century. Some of those escaped, and others were deliberately turned loose. They spread across the continent with extraordinary speed and, within 150 years, several million horses roamed free across western North America.

### Challenging the neigh-sayers

Today, some 33,000 horses roam public lands in the western USA, with a few thousand more in Canada, Alberta, British Columbia and on Sable Island, off the coast of Nova Scotia. Are these free-roaming herds truly wild? Or are they merely domestic escapees with no ecological niche or genuine connection to other species?

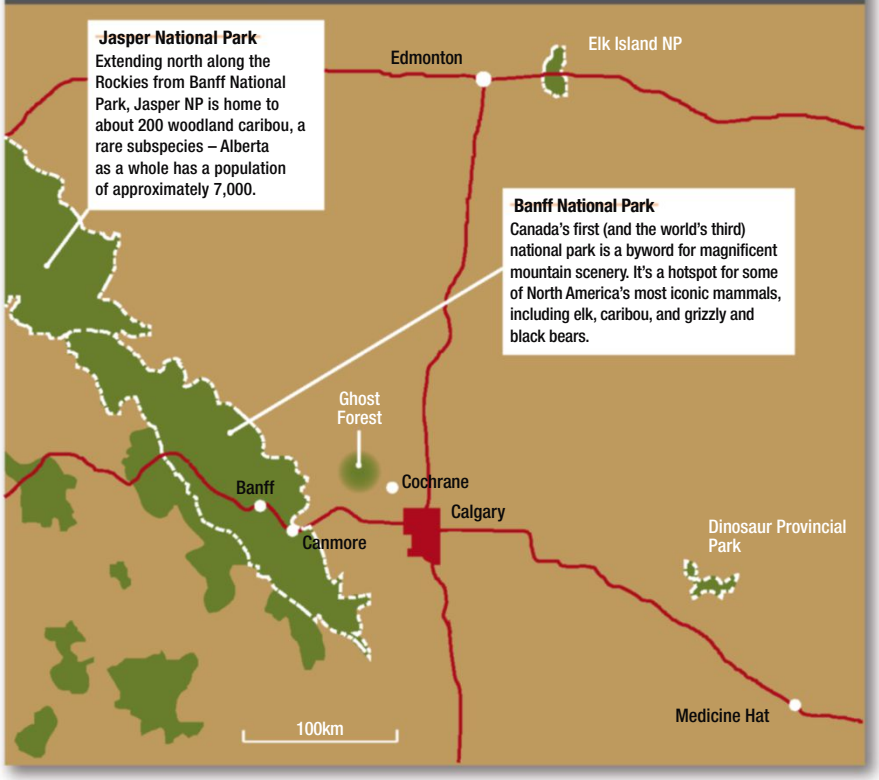
These are highly charged questions, and the answers are critical in determining how horses and their habitats are treated. Federal and state management agencies regard

Females (such as this filly) may leave the natal group of their own accord when they first come into oestrus at two or three years old

# THE INFORMATION

**ALBERTA** The eastern edge of the Rocky Mountains is an area of wild beauty, home to Canada's most iconic species.

## THE NAVIGATOR




## NOW YOU DO IT

### GETTING THERE

▶ Airlines with direct flights to Calgary include **Air Canada**, www.aircanada.com and **British Airways**. www.britishairways.com

### GETTING AROUND

▶**The Banff Airporter** bus serves Cochrane, Canmore and Banff from Calgary Airport. www.banffairporter.com

### RIDING AND ACCOMMODATION

▶ **Wild Deuce** offers wilderness riding and trains horses according to the social bonds of the wild herds. http://wilddeuce.com

▶**Moose Mountain Horseback Adventures** runs trips into the high country around the Ghost Forest, tailored to guests' interests and abilities. www.packtrips.ca

▶ **Sierra West Cabins & Ranch Vacations** is a working ranch offering riding and cattle drives. http://sierrawestcabins.com

### FURTHER READING

▶ **Online guide to Alberta** Practical tips, weather, wildlife and camp sites. www.travelalberta.co.uk

▶ **Western Canada** by Matthew Gardner and Alison Bigg (Footprint, ISBN 9781907263255).

▶ **Wild Horses, Wild Wolves: Legends at Risk at the Foot of the Canadian Rockies** (above) by Maureen Enns (Rocky Mountain Books, ISBN 9781927330234). Maureen Enns untangles old myths relating to the wild horses of the Ghost Forest.

Wolves rarely prey on horses, though they evolved alongside each other.

COUGAR: MICHAEL DURHAM/NPL; HORSE & WOLF: MAUREEN ENNS

horses as an intrusive, feral species and manage them accordingly. In the USA, wild horses are regularly removed from the range, many spending the rest of their lives in holding facilities. Canadian wild horses, too, have little real protection. The forests where they live may be clear-felled, the horses captured and sent for slaughter for meat.

Indeed, the Ghost Forest itself is under imminent threat: a great swath has been selected for clear-felling. If the horses lose their habitat, they will become more vulnerable to capture and slaughter – unless they can be given protection as part of the natural heritage of Alberta. This has already been accorded the wild horses of Sable Island, which were given the status of 'native wildlife' in 2012.

Her years of study have convinced Maureen that the horses of the Ghost Forest deserve similar recognition. They are part of the ecological community, and their intelligence and power have been honed by the many challenges they face.

We leave the forest through the clearing above the lake, where the band of six bachelor stallions is still grazing. This time they spot us and, drawn by Maureen's elegant mare, they break into a canter and approach. The graceful motion of a horse is one of the wonders of the natural world, and these wild individuals move with a fluid, harmonious ease that is breathtakingly beautiful.

"Keep Amigo close to Hope," Maureen says, as the stallions enter the clearing and trot a half-circle behind us. If these were domestic stallions running loose, we would now be in real danger. They would crowd and jostle the mare, trapping us in a melee of kicks and squeals. I tense, fearing Amigo might panic and bolt.

The energy of the horses' compulsion and the rapid rhythm of their strides fill the clearing. They halt for a moment to watch us through the tree trunks, then keep pace as we urge our horses forward, but never intrude on our space.

And that's how I see them last: all poised alertness, their dark heads raised, as they watch us from the aspen trees – wild creatures, fully at home in their own world, living free from the pressures of the human will.

**ELEANOR O'HANLON** is a writer whose articles have appeared in magazines in Europe and North America. Her book *Eyes of the Wild* is out now.

# ULTIMATE TEST: DRIVING INTO THE FUTURE

What technology will you find in your next car? **Daniel Bennett** test-drives the world's smartest motors to find out

Want to know what features your next car might have? Then you don't need to look much further than the flagship models of today. Like a shop window, manufacturers pack their smartest wares into these machines to showcase the technology and design they intend to endow the rest of their cars with From automated driving to 360-degree cameras to night vision mode, we test the four most high-tech cars on the road today to find out what you might be driving tomorrow...

# BMW M4

www.bmw.com

These days, a good measure of whether something's 'modern' or not is whether it has its own app. The M4 has two. Between them they can access your social networks, podcasts and show you where you parked your car (though we'd hope not to need that feature too often). The most useful thing of all they can do is pick apart the telemetry from your car's engine to tell you how you've been driving and precisely what to do to start saving some money on petrol. Following the app's instructions, we gained an extra 5mpg.

The computer onboard the car itself was easily the most intuitive to use. It blinked between menu screens instantly, with all the options oriented around a single dial while keeping the sat-nav displayed on the right-hand side of the screen at all times. There was hardly any waiting around when we used Google maps data to find us the nearest pub to a small B road in south Wales. There's a built-in web browser too, which is less snappy, but a welcome addition should you need to look something up. Once your destination is primed, the directions also pop up on your windscreen via a Heads-Up Display (HUD), along with a progress bar that fills up as you close in on the next turn. This means you rarely have to take your eyes off the road.

While you drive, the cameras are also busy reading the nearest road signs to project the current speed limit alongside your actual speed on the HUD. These cameras also work with radar detectors on the nose and rear end of the M4 to help you park. They actually highlight obstacles as you approach them, going from green to red as you get nearer.

BMW's offering might not be as pioneering as the Mercedes, but it pulls off everything it does offer supremely well.


## FASTER SOUNDS

The M4 will let you stream music from an ever-growing number of online stores and internet radio stations

| | |
|---|---|
| ENGINE SIZE | 2,979 CC |
| HORSEPOWER | 431HP @ 5,500 RPM |
| MPG* | 32.1 MPG |
| 0-60MPH* | 4.3 seconds |
| DIMENSIONS | 4.7 X 1.9 X 1.4M, 1,612KG |

*Manufacturer's quoted figures

PHOTO: THESECRETSTUDIO.NET

# AUDI A8

www.audi.com


## TRACKING TRAFFIC

Future Audis will include a system that tells the driver how fast to travel to avoid stopping at the next set of lights

| | |
|---|---|
| ENGINE SIZE | 2,967 CC |
| HORSEPOWER | 255 HP @ 4,000RPM |
| MPG* | 47.1 MPG |
| 0-60MPH* | 6.1 seconds |
| DIMENSIONS | 5.3 X 1.9 X 1.5M, 2,585KG |

The A8 is elegant and understated. In fact, before the keys landed in our hands it had been chauffeuring celebs to and from the BAFTA awards. Inside, the ergonomics of every button, stick and switch have carefully thought out. For example, since the gear lever is flat like a boat's throttle, it's where you'll naturally rest your left hand. Knowing this, Audi has placed all the most used controls a finger's stretch away from this spot.

The same design ethos runs into the intuitive Audi Connect system, which manages the car's settings, sat-nav and multimedia. For instance, you can input addresses and postcodes by drawing them out with your finger on the central touchpad. It's much quicker than relying on the car's central 'jogwheel', and it successfully translated our crude chicken scratching into letters. Once the car pulls away, the touchpad displays the numbers 1-6 so you can select your favourite radio stations quickly. Your sat-nav directions are then beamed onto the windscreen by the car's HUD, along with safety warnings if you start getting too close to the car in front. There's even an update coming which will be able to tell you what speed to maintain to avoid having to stop at the next traffic light – thus saving you fuel. And the 360-degree camera, which takes radar images from around the car and compiles them into a top-down view, means parking will never be difficult again.

Unlike the other cars, the A8 drinks diesel. It's also a relatively small three-litre engine block, but Audi has clearly taken the lessons it's learned beating petrol cars in 24-hour races and put them to good use. It can be frugal and quiet one second, ferociously fast the next, while the four-wheel drive system makes you feel glued to the road at all times, and forget you're in something the size of a yacht.

# LEXUS LS 600H

www.lexus.com

Panelled with walnut and draped in leather, the LS 600h has all the opulence of a stately home. But beneath the old-fashioned demeanour is a strikingly modern petrol-electric hybrid engine – similar in a sense to what you'd find in a Toyota Prius.

Tacking an electric motor onto a five-litre V8 might seem futile ecologically speaking (though we did average around 28mpg), but it's not there to save the planet. What it is there to do is move quickly and silently. Unlike a petrol engine, the battery-powered motor, which is charged from the wheels when the car coasts, can deliver all of its power the second you stamp your foot on the pedal. This means if you need to move all 2.8 tonnes of the car in a hurry, you don't need to wait for the petrol engine to reach its peak rev range. And since this is a bit of a limousine it doesn't hurt that it'll do all this silently, too.

Most of the technology throughout is channelled to do that very job – keep everything serene. The LS 600h was the car in which we felt most isolated from the outside world. Even on the noisy, potholed M25, the inside of the cabin was relatively sedate.

Again, the car is always casting a watchful eye over the road. Radar that is sensitive enough to pick up individual pedestrians monitors the adjacent lanes and sends out a warning if you start to switch lanes without checking your blind spot – all the while monitoring the car in front in case it needs to ready the brakes and safety systems for a crash.

Unfortunately, the on-board computer isn't as smart or as relaxing to use as the rest of the car. It's controlled via a small joystick, which more often than not causes you to glide over the option you wanted. Generally speaking it slows everything down, and puts you off using the clever features packed behind its 12-inch display.


## ACQUIRING APPS

The LS 600h can be improved with apps that give you access to local information and radio from around the world

| | |
|---|---|
| ENGINE SIZE | 4,696 CC |
| HORSEPOWER | 389HP @ 6,400 RPM |
| MPG* | 32.8 MPG |
| 0-60MPH* | 6.2 seconds |
| DIMENSIONS | 5.2 X 1.9 X 1.5M, 2,815KG |

PHOTO: THESECRETSTUDIO.NET

# MERCEDES S500 AMG L

www.mercedes-benz.com


## PRECISION PARKING

The S500 uses cameras around the car to display your exact position from above, as well as the view from the rear camera

| | |
|---|---|
| ENGINE SIZE | 2,967 CC |
| HORSEPOWER | 255 HP @ 4,000RPM |
| MPG* | 47.1 MPG |
| 0-60MPH* | 6.1 seconds |
| DIMENSIONS | 5.3 X 1.9 X 1.5M, 2,585KG |

This is easily one of the most advanced machines I've ever experienced. On the surface, the luxuries are easy to spot. A vaporiser diffuses perfume, the chairs give hot stone massages and the sound system pumps out pin-sharp music. But strip away these extravagances, and the S500 is still miles ahead of its rivals.

Intelligence seems to be wired into the very chassis of the S500. A pair of cameras behind the rear view mirror scan the road ahead, scouting for bumps and potholes. When they find one, the whole body leans over to one side to reduce the impact – the car genuinely seemed to glide over speed bumps. These cameras also keep an eye on the car in front: the S500's computer will spot an accident before you can, and ready the brakes in anticipation. Fail to react and the car will sound warnings before hitting the brakes for you. Thankfully we didn't have to test this out!

After dark, an infrared camera behind the radiator keeps watch. You can monitor this from the dash, but the car is always looking for animals or people in the road. If a person steps out the car flashes its headlights, but if the car detects an animal on the tarmac, it only warns you, for fear of startling the animal.

The S500 will even do the driving for you. On motorways, we engaged the Distronic Plus system – a kind of robotic chauffeur – which steered the S500 between the white lines at a constant speed, only slowing when the car in front got closer. We kept our hands on the wheel, but otherwise just sat back and enjoyed the ride – for several hundred miles.

In truth, we'd need a few more pages to fit in all the tech found inside the S500, like the blind spot warnings, the 360-degree parking camera and more. For now all we can say is that we hope this is where car technology is heading.

# CELEBRATE WILD WILD WET'S 10th BIRTHDAY BASH!

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### (30 pairs to be won)

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Celebrate our 10th Birthday Bash on 2nd August with fun filled activities and games. Amidst the unusual water-based percussion sounds, our life-sized sea creature mascots will be joining our festive splash! On top of that, there is also dive in for the Aqua Zumba dancercise in water to Latin and other international musical beats.

Make your Wild Wild Wet visit extra fun with games specially prepared for our birthday, so do take part in our contest from 14 July to win free entry to the party. Visit Downtown East on Facebook for more details.

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**www.wildwildwet.com**

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Send your entry via email to **marketing@regentmedia.sg** or post it to: BBC Knowledge Magazine / NTUC Club Promotion, Regent Media Pte Ltd, 20 Bedok South Road, Singapore 469277.
**Closing date: 31 JULY 2014**

**Question: Name any 2 rides in Wild Wild Wet.**

NAME: ..... AGE: .....

OCCUPATION: .....

NRIC: ..... DOB: .....

ADDRESS: .....

.....

HP: .....

EMAIL: .....

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# Q&A

# YOUR QUESTIONS ANSWERED

## BY OUR EXPERT PANEL

**SUSAN BLACKMORE**

Susan is a visiting psychology professor at the University of Plymouth. Her books include *The Meme Machine*

**DR ALASTAIR GUNN**

Alastair is a radio astronomer at the Jodrell Bank Centre for Astrophysics at the University of Manchester

**ROBERT MATTHEWS**

After studying physics at Oxford, Robert became a science writer. He's a visiting reader in science at Aston University

**GARETH MITCHELL**

Starting out as a broadcast engineer, Gareth now writes and presents *Digital Planet* on the BBC World Service

**LUIS VILLAZON**

Luis has a BSc in computing and an MSc in zoology from Oxford. His works include *How Cows Reach The Ground*

editorial-bbcknowledge@regentmedia.sg

Q

## What's the largest floating object in the world?

A It's Shell's Prelude Floating Liquefied Natural Gas vessel (pictured). It's nearly half a kilometre in length with a displacement in the water equivalent to six aircraft carriers. It became the largest hull ever to be floated in November last year, after 14 months of construction at Samsung's shipyard in Goeje in South Korea. With the hull complete, and weighing over 200,000 tonnes, it was moved to another part of the shipyard for its liquefaction modules to be fitted.

The FLNG is being built to tap a natural gas reserve off the coast of Western Australia. The reserve is too remote for the gas to be piped to land. Instead, the FLNG will liquefy the gas at sea.

Strictly, the vessel is not a ship as it does not travel under its own power but instead will be towed into position. When completed it will weigh 600,000 tonnes and produce gas equivalent to Hong Kong's annual consumption. **GM**

"We're not gonna need a bigger boat"


PHOTO: SHELL

# Q&A

**In Numbers**

**3,253**

seconds is the time that an ARM-processor-powered robot made from Lego solved a Rubik's Cube, beating the previous record of 5.27s.

## Why is the Arctic warming faster than the rest of the planet?

**A** While the average temperature of the Earth has increased by around 0.8°C over recent decades, the Arctic is warming twice as fast. Recent research by climatologists suggests this is because a peculiar atmospheric layer over the Arctic traps in heat that would otherwise escape. The disappearance of highly reflective sea-ice also boosts the effect. **RM**

The Arctic is warming twice as fast as the rest of the planet

## Is the Great Wall of China really visible from space?

**A** No. Even from low Earth orbit the Great Wall of China is extremely hard to spot with the naked eye. It's a very thin line, almost the same colour as the landscape. Lots of other things are visible though, including cities, airports and dams. From the Moon, no man-made structure is visible. **LV**

The Great Wall of China: big, but not big enough to see from space

## What percentage of the Universe is visible from Earth?

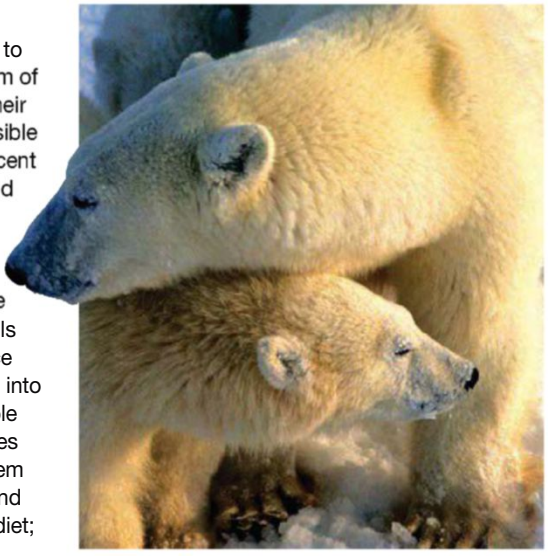
We can happily observe everything in the Universe up to 46 billion light-years away

**A** The Universe may be so big that the light emitted from its most distant regions has not had enough time to reach the Earth during its 13.8 billion year history. We will never be able to see beyond this natural 'horizon', which is currently about 46 billion light-years away. This 'edge' defines what astronomers call the 'observable Universe'. Our most powerful telescopes can pick up signals that lie right at this limit of observability so it would be correct to say we can see 100 per cent of the 'observable' Universe.

However, the Universe is probably much bigger than just the part we can see. Unfortunately, at present we have no way of deciding exactly how big the Universe is or even whether it is finite or infinite. So, it's not possible to say what percentage of the 'entire' Universe we can observe from Earth. **AG**

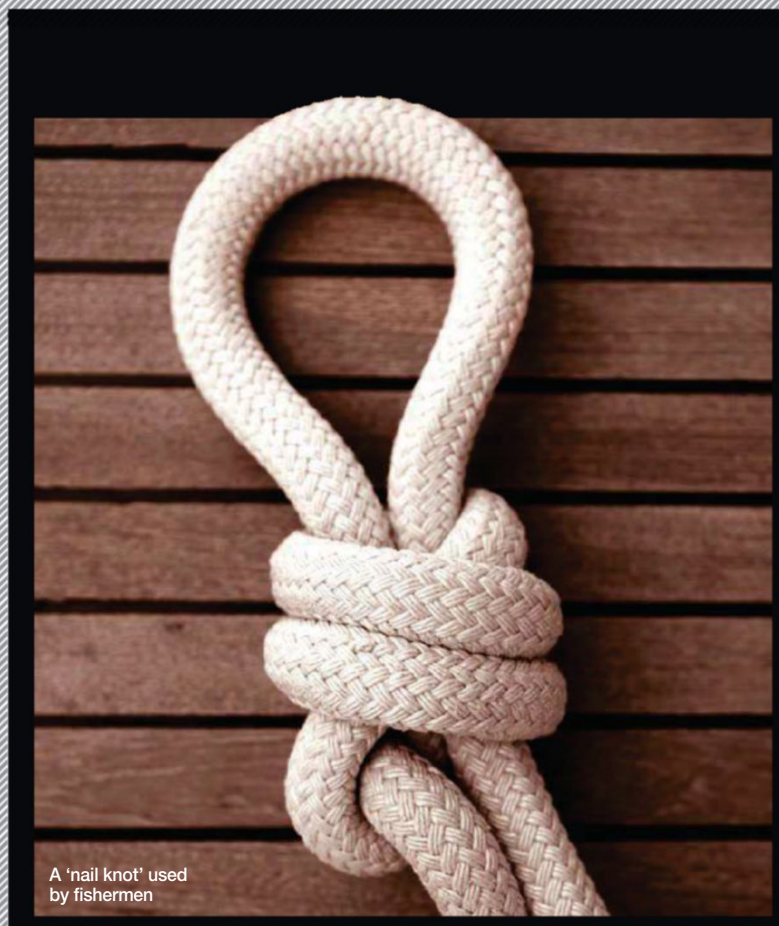
## How do polar bears stay warm?

**A** They are incredibly well insulated with a layer of blubber that can be up to 10cm thick covered with another 15cm of fur. Polar bears lose so little heat to their environment that they are almost invisible to thermal imaging cameras. But a recent study at the University of Buffalo found that polar bears have also evolved genes that produce more nitric oxide than other bear species. Nitric oxide is a signalling molecule and one of the mechanisms it controls is whether cells use their available nutrients to produce metabolic energy, or simply convert it into body heat. Polar bears seem to be able to divert more of their body's resources into generating heat. This relies on them getting enough fuel for this process and adult polar bears have a high calorie diet; they mostly eat seal blubber. **LV**



The polar bear is a master of heat management

PHOTO: ALAMY X3, THINKSTOCK X2, GETTY, SCIENCE PHOTO LIBRARY



A 'nail knot' used by fishermen

Q

# How many different types of knots are there?

A People have been inventing knots for millennia; the oldest known – used in a fishing net found in Finland in 1913 – dates from around 8000BC. Thousands are now known, but they're not all unique: some are just combinations of others.

Actually deciding whether two apparently different tangles of string are really just the same knot in disguise or some combination is far from simple. So to bring some order to the chaos, mathematicians have developed ways of classifying knots. This has revealed the existence of truly fundamental ones that can't be unravelled into collections of simpler ones.

Taking prime numbers as an analogy – which can't be divided by anything other than themselves and one – these are so-called prime knots. The simplest is the so-called trefoil knot; a combination of two of these form the famous 'granny knot'. There's an infinite number of prime knots, and these form an infinite number of composite knots. I wouldn't go trying to untangle them all! **RM**

It's a smelly job, but someone's got to do it

Q

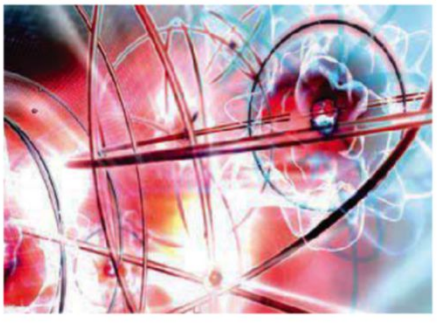
# Why do we get used to smells?

A Our nervous system has evolved to become progressively less sensitive to a stimulus, the longer it persists. This enables us to concentrate on the newest sensations that are more likely to be an opportunity or a threat. We also have an olfactory memory that discards smells that we have experienced recently. This means that you don't notice the smell of your house when you come home from work, but it smells strange when you come back from holiday. **LV**

Q

# What keeps electrons moving?

A Electrons are often portrayed whizzing round the nuclei of atoms like planets orbiting stars. Theory shows, however, that if electrons really did behave like this, they'd rapidly lose energy and crash into the nuclei. The reality is much more abstract, with electrons being more like fuzzy clouds surrounding the nuclei. **RM**



The traditional view of an electron whizzing round a nuclei may not be accurate; they'd lose too much energy

# Q&A

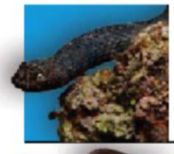
## TOP TEN
### DEADLIEST SNAKES

Based on the $LD_{50}$ (lethal dose 50%) test - the amount of venom required to kill half a test pool of mice, expressed in mg/kg

**1. Hook-nosed seasnake**
**$LD_{50}$ (mg/kg):** 0.02
**Length:** up to 1.5m
**Location:** South Asia waters

**2. Russell's viper**
**LD50 (mg/kg):** 0.03
**Length:** up to 1.7m
**Location:** Asia

**2. Inland taipan**
**LD50 (mg/kg):** 0.03
**Length:** up to 2.5m
**Location:** Australia



**4. Dubois's reef seasnake**
**LD50 (mg/kg):** 0.04
**Length:** up to 1.5m
**Location:** Australian waters

**5. Eastern brownsnake**
**LD50 (mg/kg):** 0.05
**Length:** up to 2.4m
**Location:** Australia, Papua New Guinea, Indonesia

**5. Black mamba**
**LD50 (mg/kg):** 0.05
**Length:** up to 4.5m
**Location:** Sub-Saharan Africa

**7. Tiger rattlesnake**
**LD50 (mg/kg):** 0.06
**Length:** up to 0.9m
**Location:** Southwestern USA

**8. Boomslang**
**LD50 (mg/kg):** 0.07
**Length:** up to 2.0m
**Location:** Sub-Saharan Africa

**8. Yellow-bellied seasnake**
**LD50 (mg/kg):** 0.07
**Length:** up to 1.1m
**Location:** Pacific, Indian Oceans

**10. Common Indian krait**
**LD50 (mg/kg):** 0.09
Length: up to 2.1m
Location: India

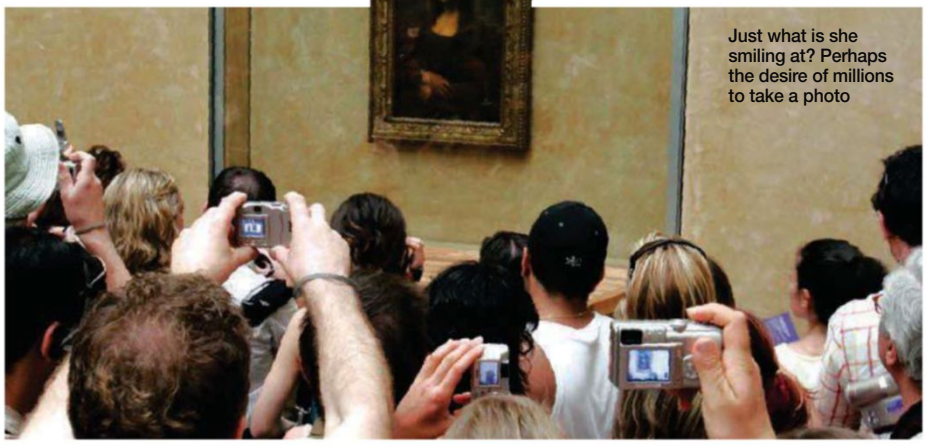
PHOTO: THINKSTOCK X2, PETER WOODARD/WIKIPEDIA, ALOAIZA/WIKIPEDIA, NIGEL MARSH/SEAPICS.COM, ALAMY X5, SUPERSTOCK, SCIENCE PHOTO LIBRARY

Q

# Does taking pictures help us remember things?

A Sometimes, but it can also do the opposite. Photography can spoil our memories if we rely on having pictures to take home instead of enjoying life as it happens. Tourists who hold their phones or cameras up all day cannot look properly at the sights, let alone engage deeply with people and emotions. A specific 'photo-taking-impairment effect' was recently discovered when students photographed 15 objects in a museum and just looked at 15 others. They remembered less detail of the photographed items. However, the effect was fragile. If they zoomed in on specified areas of the objects, they recalled more details not fewer, even recalling details that were not in the photos.

Indeed photographs can help memory in other ways. Concentrating while choosing a shot requires attention which in turn aids memory. And looking at photos later helps us remember more about the context and the events we chose to record. **SB**



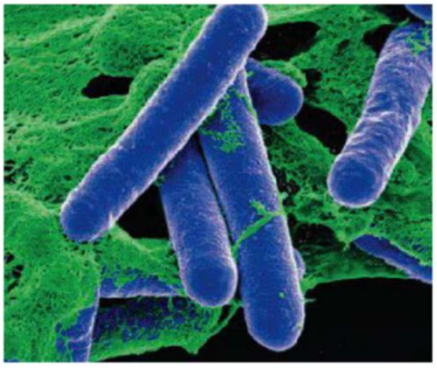
Just what is she smiling at? Perhaps the desire of millions to take a photo

Q

# If you could store food in a perfect vacuum, how long would it remain edible?

A Food spoils because of chemical changes and the growth of bacteria. There are plenty of bacteria that don't need oxygen to survive and some of the most dangerous ones actually require an oxygen-free environment to grow. Vacuum-packing food can actually activate the spores of *Clostridium botulinum*, which causes botulism, for example. So a vacuum doesn't protect food by itself. Food that is vacuum sealed is first cooked to kill any existing bacteria and then packaged to prevent new bacteria getting in. Vacuum packing is about as effective as canning in this regard and some foods can last several years.

If you just expose food unprotected to a vacuum, it will rapidly lose moisture. This prevents bacteria from growing, but it also changes the taste and texture of the food. To preserve flavour, the dried strawberries in some breakfast cereals are preserved by freezing them and then drying them in a vacuum. **LV**



*Clostridium botulinum* wakes up when it finds itself in a vacuum and can then make you very ill indeed

BBC Knowledge

# Highlights

## TV Channel

### Welcome to India

Premieres 8th July. Tuesdays at 7.05pm (JKT/BKK), 8.05pm (SIN/HK/MAL/TWN)

From a shipbreaker who dismantles ocean going ships with a handheld acetylene torch, to the ambitious lady who builds a waste bottle sorting empire on a railway embankment, delve into the heart of India as this series uncovers the incredible and visually arresting stories of the lives of the Indian people.

### Duck Quacks Don't Echo

Premieres 6th July. Sundays at 8.00pm (JKT/BKK), 9.00pm (SIN/HK/MAL/TWN)

Each episode of *Duck Quacks Don't Echo* sees three celebrity contestants bringing with them an incredible fact and arguing passionately for why their fact is absolutely true and why it should win.

### Deadly 60: On a Misssion Sr 2

Premieres 10th July. Thursdays at 8.25pm (JKT/BKK), 9.25pm (SIN/HK/MAL/TWN)

Join Steve Backshall and his trusty crew in search of the biggest, fastest, most venomous animals in his deadliest series ever.

### Great Bear Stakeout

Premieres 24th July. Thursdays at 8.55pm (JKT/BKK), 9.55pm (SIN/HK/MAL/TWN)

Using a huge stakeout team and a range of cameras, this stunning series takes you right into the heart of grizzly bear central -a magical location in wildest Alaska.

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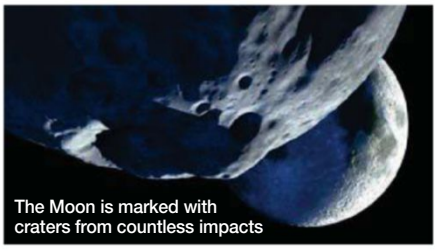
# Q&A

## What would happen if an asteroid hit our Moon?

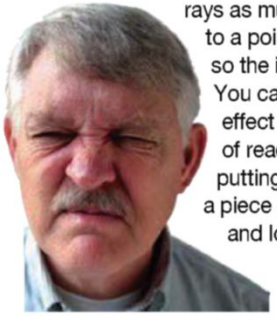
Most asteroids are small and slow enough to simply hit the Moon and create a new crater. Even the largest asteroid, Ceres, at 975km (605 miles) in diameter, probably wouldn't cause much lasting damage, although it would be a spectacular explosion viewed from Earth! It would take an object similar in size to the Moon to break the Moon up or send it hurtling into the Earth. **AG**



The Moon is marked with craters from countless impacts

## Why can we see clearer when we squint?

Squinting uses the muscles of the cheeks and eyebrows to close up the eye. This blocks out some of the light, so the image is darker, but what is left is the light coming in at the shallowest angles. Your eye doesn't need to bend these rays as much to bring them to a point on your retina, so the image is in focus. You can exploit this effect to make a pair of reading glasses by putting pin holes in a piece of cardboard and looking through that. **LV**



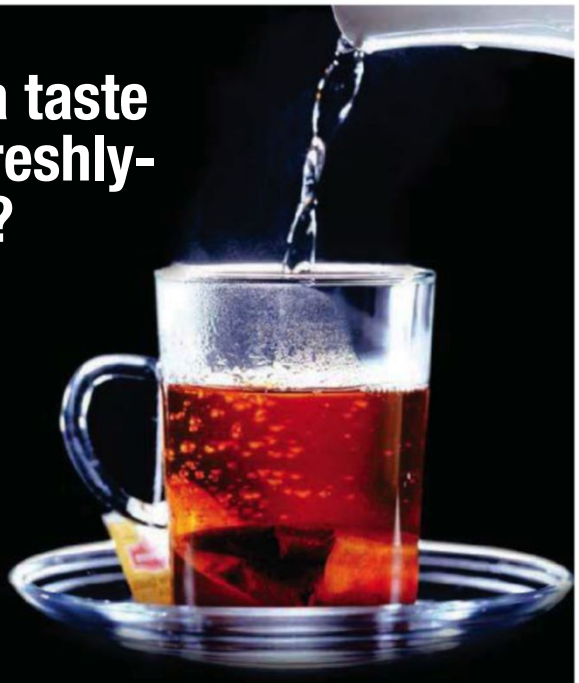
Hopefully you aren't having to squint to read this

**In Numbers**

**1,300**

times the diameter of the Sun, is the size of the largest yellow star ever discovered. The 'hypergiant' star is called HR 5171 A.

## Why does tea taste better with freshly-boiled water?



To re-boil or not to re-boil, that is the question

Packets of tea often say 'boil freshly drawn water' and a famous brand gives 'Monkey's top tips': 'Use fresh tap water: it contains more oxygen, which makes for a fuller flavour.' What's more, tea expert Simon Hill, a buyer from Taylors of Harrogate claims that if water is boiled twice "the taste is flatter and the colour is duller and less reflective". You might assume that experiments have been done to reach this conclusion, such as blind tastings comparing cups of tea made with water boiled 10 times or just once. But no such experiments have been published.

But maybe freshly boiled water does make a difference. For example, dirt or limescale in the kettle might affect the taste after repeated boiling. But could the oxygen theory be true? No. If you heat a pan of water you can see the first bubbles coming off long before the water boils. These are dissolved gases coming out of solution. This means that most of the oxygen has gone long before boiling point, leaving deaerated water. So re-boiling should make no difference – the oxygen has already gone. Yet because of this myth some people throw away water left in the kettle and start again. Some even think that if they boil a kettle and then leave it for a few minutes, they must throw the hot water away and start again. What a waste of energy! **SB**

## What happens to worms when the ground floods?

Earthworms don't have lungs or gills; they absorb oxygen directly through their moist skin. Earthworms don't drown and can survive for several weeks in water if it is kept oxygenated. In flooded soil though, oxygen diffuses more slowly and plant roots absorb what little there is, so the oxygen in the worm's burrow can become rapidly depleted. Some species have low enough metabolic rates that they can tolerate this, but the common garden worm Lumbricus terrestris will surface after heavy rain to get some air, until the soil drains. **LV**

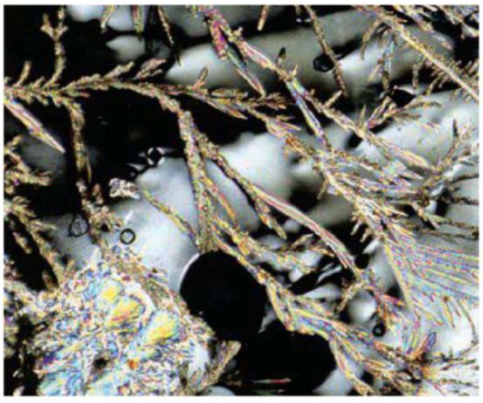
When you see earthworms on your lawn on a rainy day, have a little sympathy - they're gasping for air

PHOTO: SCIENCE PHOTO LIBRARY, ALAMY X2, PRESS ASSOCIATION

# What causes addiction?

Addictive drugs interfere with neurotransmitters, the chemicals that transmit signals around the brain, and their receptors. This causes changes to the brain's reward system. This can create craving and tolerance, so that a higher dose is needed to have the same effect. Some also have unpleasant withdrawal symptoms that are only relieved by taking more. Heroin is the most addictive drug known. It mimics the brain's own endorphins, the natural opioids that induce pleasure and reduce pain. The brain responds by reducing the number and sensitivity of its opioid receptors so that more of the drug is needed. Nicotine increases dopamine and activates the brain's rewards pathways. Again, the brain compensates so that more nicotine is required.

People can also become addicted to activities such as sex, gambling or shopping, but the mechanisms underlying these addictions are less well understood. **SB**



Heroin, seen here under a micrograph, alters the brain's reward system leading to addiction

# At what altitude can you see the curvature of the Earth?

From Felix Baumgartner's world record skydive to teddy bears carried aloft in balloons, we're all familiar with photos taken from 'the edge of space', with the curvature of the Earth in clear view. It's all a bit of an exaggeration, though: even Baumgartner's 39km (24-mile) high jump was well below the 100km (62-mile) height usually taken to be where space begins.

Passengers on Concorde were able to see the curvature of the Earth, implying that an altitude of 60,000ft (18.3km) is more than enough. Pilots and cabin staff flying considerably lower have sometimes claimed to have seen the curvature too, but there's long been a suspicion that they were being fooled by optical distortion by windows. To get to the bottom of the mystery, Dr David Lynch of California-based optics consultancy Thule Scientific carried out a detailed analysis, published in the journal Applied Optics in 2008. He concluded it's just possible to see the curve of the Earth at around 35,000ft (10.7km) – given perfect conditions. This suggests that the curvature of the Earth can be seen from heights barely 10 per cent of the height of the threshold of space. **RM**

Felix Baumgartner could see the curvature of the Earth, but he wasn't technically in space

# Q&A

## How do you fix a sinkhole?

A Sinkholes form in chalk or limestone areas where the bedrock is eroded by underground streams, leaving a thin roof that eventually collapses. You can repair small ones by excavating down to stable bedrock and then filling in the hole with concrete. But concrete creates an impermeable plug that diverts subsurface water around it and can actually accelerate erosion. For larger holes, it is better to fill most of the void with large rocks and boulders that leave gaps for drainage, layering smaller grades of rocks, gravel and finally sand. **LV**

You'll need a lot of concrete to fill up a sink hole

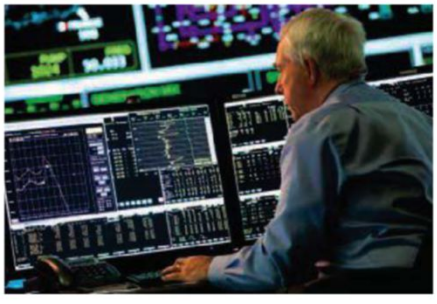
## Are all dogs descended from wolves?

A Yes. Before the advent of DNA sequencing, it was thought that dogs might have jackal and coyote ancestors as well as wolves, but this has now been disproved. The grey wolf (Canis lupus) was first domesticated some time between 15,000 and 33,000 years ago, probably by hand rearing the orphaned pups of adult wolves that had been hunted. Selective breeding slowly favoured the traits most useful to humans. Some modern breeds, such as the Alsatian, may be the result of later cross-breeding with wolves to reintroduce some wild characteristics. **LV**

The Chihuahua's distant ancestor - the grey wolf

## Will we have more electricity blackouts in the future?

A A joint study published earlier this year by the University of Lincoln and the University of Auckland concludes that we will. The study analysed energy supply and consumption across the major Western countries. From here it projected an 80 per cent growth in demand worldwide by 2035, requiring an additional 5,900 gigawatts of power. If we continue to build power stations at the present rate, supply will fall short and the lights will go off more often. **GM**



This chap at the UK's Electricity National Control Centre is going to have a tough job come 2035

## How do we know what the Milky Way Galaxy looks like?

You can see the plane of stars that make up our Galaxy by looking up at the Milky Way on a clear night

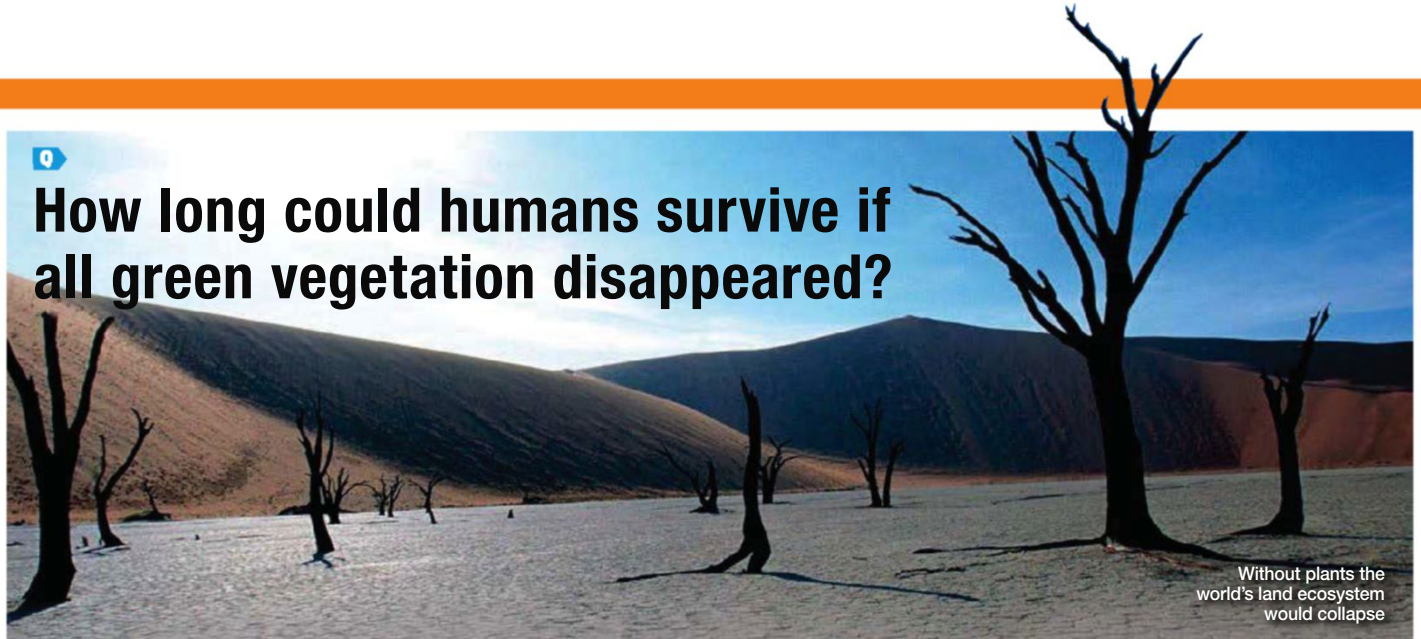
A It is, of course, difficult to deduce the appearance of something when you are embedded within it! But astronomers can map the distribution of the stars and their motions quite easily. This shows us that the stars of the Milky Way are orbiting a central 'bulge' (in the constellation Sagittarius) and are distributed in a thin plane.

The most convincing evidence for the spiral structure of the Milky Way comes from studies of gas clouds. By measuring the velocities and positions of these clouds, astronomers are able to show that they are distributed in a loose spiral pattern around the galactic centre. However, astronomers are unsure how many spiral arms there are.

So, although we can't see the Milky Way from the outside, the evidence suggests it has a structure much like the other spiral galaxies we see around us. **AG**

PHOTO: CORBIS, THINKSTOCK X3, ALAMY, SCIENCE PHOTO LIBRARY, THE NATIONAL GRID

# How long could humans survive if all green vegetation disappeared?



Without plants the world's land ecosystem would collapse

**A** If green plants literally vanished, there would be massive floods and landslides as the soil lost the stabilising effect of plant roots, and rainwater ran straight off the surface. If they were all killed by a mysterious virus, there would be enormous wildfires as dead forests became tinder-dry.

Long before that almost every land ecosystem would have collapsed as the herbivores, and then the carnivores, starved to death. Humans probably wouldn't die out completely though. Existing food stocks would last about a year in developed countries and we could still get food from the sea. Marine ecosystems depend on the photosynthesis of unicellular algae, rather than green plants. We might even be able to cultivate the algae ourselves. Marine algae also produce about 50 per cent of Earth's oxygen, so there would still be plenty to breathe – particularly since we would be virtually the only land animal left. **LV**

Extracting oil is like sucking it from a sponge

# What fills the spaces left by oil extraction?

**A** Oilfields aren't vast underground caves filled with oil that form empty voids as the oil is pumped out. Rather, the oil seeps through layers of porous sandstone or limestone rock, and collects in places where an impermeable rock layer prevents it from rising to the surface. Extracting oil is more like sucking from a sponge than drinking through a straw. When the oil is removed, the pressure from the surrounding rock forces groundwater into the gaps. As the oilfield is depleted, more and more water comes out along with the oil, until it's uneconomical to extract any more. **LV**

## YOUR QUESTIONS ANSWERED

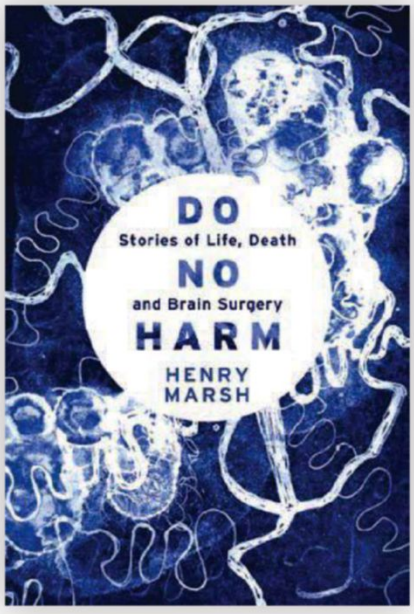
Email to **editorial-bbcknowledge@regentmedia.sg.**
We're sorry, but we cannot reply to questions individually.

P Paperback H Hardback

# Do No Harm

## Stories Of Life, Death And Brain Surgery

**Henry Marsh**
Weidenfeld & Nicolson H




This is a deeply compassionate account of a professional life spent on the edge, a job which has huge highs and appalling lows. As Henry Marsh writes in the preface: "A brain surgeon's life is never boring and can be profoundly rewarding, but it comes at a price. You will inevitably make mistakes and you must learn to live with the occasionally awful consequences."

A few years ago I made a television series on the history of surgery, which included a programme about neurosurgery. It began with me chatting to a young woman lying on an operating table while a neurosurgeon removed a tumour from her brain. They had to operate while she was fully conscious to reduce the risk that, along with the tumour, the surgeon would accidentally remove normal, healthy brain tissue.

This is the dilemma that all neurosurgeons face. They are operating on a part of the body (if you can describe the brain that way) where there is no scope for error; where even the slightest mistake can have profound repercussions. The human brain is unbelievably complex, but that also makes it extremely vulnerable.

Henry Marsh is a world-class neurosurgeon but he is also a great storyteller. Take, for example, his description of an operation to remove an aneurysm – a weakened artery – from deep within the brain of a 32-year-old woman. He thinks an operation is too dangerous, but she wants it removed. Towards the end of the operation, when he is ready to clip the artery, the instrument he's using to do so fails. It is a heart-stopping moment.

Henry Marsh knows that he has to do something, but he doesn't know what: "I cannot move my hand for fear of tearing the minute, fragile aneurysm… and causing a catastrophic haemorrhage. I sit there motionless, with my hand frozen in space." He knows that the slightest mistake will lead to this young, healthy woman suffering a major stroke and permanent brain damage. He has to act but how? The situation is unbearably tense, and makes for a page-turner.

Fortunately, in this case all ends well, but how many of us would want to face those dilemmas on a regular basis as part of our daily lives? I once thought I would like to be a neurosurgeon; now I am glad that I took a different path.

This is an extraordinary book by an extraordinary man.

**"The slightest mistake will lead to this young, healthy woman suffering a major stroke"**

**DR MICHAEL MOSLEY** is a journalist and presenter who returns to BBC TV in *Trust Me I'm A Doctor*, coming soon

## MEET THE AUTHOR

### Henry Marsh

**Why did you write the book?**
There's a great myth about brain surgery that it's terribly difficult – actually it's not if you know what you're doing. But it is difficult in the sense that it's very dangerous and the problems it presents to both surgeon and patient are very real. I wanted to write about that. Another reason for writing the book is that, although life as a brain surgeon is often harrowing, it is also often very wonderful. As I've got older I've been filled with an increasing sense of awe at the fact that everything we think and feel is the electrochemical chatter of our brain cells.

**Is it nerve-racking to cut into someone's brain?**
When operating, you know that if you cause damage you'll have a damaged patient at the end, so you're always anxious. It's exciting, but it's never exhilarating until the patient's woken up and is all right. I remember once being in a casino watching people gambling, and the absolute intensity with which they watched that roulette ball reminds me of the intensity you have when operating.

**Are some operations more challenging than others?**
They're all dangerous, but there are degrees of danger. Technically, the most difficult are some of the big, slow-growing benign tumours that grow underneath the brain off the skull. The operation that led me to become a neurosurgeon was aneurysm surgery, where you're dealing with blowouts on blood vessels to the brain. It's bomb disposal work for cowards – the surgeon's life isn't at risk, but the patient's is.


## The Extreme Life Of The Sea

**Stephen R Palumbi and Anthony R Palumbi**

Princeton University Press

One of the snags of 'accessible' science books is that they can be anything but. The dazzling intellect of Dawkins and Gould can intimidate even when stripped down for mere mortals like us, so it was with some trepidation that I opened *The Extreme Life Of The Sea*.

Such reservations were swiftly quashed. It's a book full of big, juicy, well-I-never facts, written in a highly entertaining style that will appeal to all. Did you know that swordfish heat their eyeballs to improve their vision? Me neither. That such a thing as an immortal jellyfish exists? And – my personal favourite – that certain viruses infect winkles specifically so they commit suicide by losing their fear of heights?

This is a terrific book, a celebration of the extraordinary adaptations of marine life, a eulogy to the complexity of the ecosystems of the sea, as well as a lament about the potential fate that awaits the oceans if man's destructive activities continue unfettered.

It's a book for anyone who has peered into a rock pool and marvelled at its contents, and a perfect gateway – open to all – into the wonderful world of marine science.

**MONTY HALLS** is a marine biologist and BBC TV presenter


## Inheritance

**How Our Genes Change Our Lives And Our Lives Change Our Genes**

**Sharon Moalem**

Sceptre

If you were to raise a chimpanzee as a human you would still get a chimpanzee, and this tells us that the genes we inherit from our parents really do matter. But the scientific study of epigenetics is showing that our genetic destiny is not fixed at conception: how we are brought up, what we eat or even how our parents were brought up and what they ate, can affect our genes. Rats fed spinach are resistant to some cancers, because compounds in the spinach modify genes that help to fight these cancers. Female mice given vitamins can benefit their offspring by modifying their genes to make them less susceptible to diabetes.

Sharon Moalem's breezy Inheritance recounts the latest in a rapidly growing list of ways that environmental factors can alter genes, and how those alterations can influence health. We don't yet know how these effects will translate to humans, but the era of the designer gene is being ushered in, and insurance companies and your doctor will want to get in on the act. You can stay one step ahead by reading Moalem's account of this fascinating, and sometimes alarming, new field.

**MARK PAGEL** is head of the Evolutionary Biology Group at the University of Reading


## Island On Fire

**The Extraordinary Story Of Laki, The Volcano That Turned Eighteenth-Century Europe Dark**

**Alexandra Witze and Jeff Kanipe**

Profile Books

The last time clouds of ash from an Icelandic eruption paid us a visit, the result was mayhem: the cancellation of more than 100,000 flights wrecking the travel plans of 10 million people. It could, however, have been far worse. In 1783, a vast outpouring of lava from the island's Laki volcano loaded the atmosphere with noxious sulphur gases, which the weather then launched towards Europe.

As the authors observe in this fascinating account of the blast, the result was a smog-ridden summer, swiftly followed by a bitter winter, as the gaseous shroud blocked out the Sun. One-fifth of Iceland's inhabitants died during the resulting famine, while across Europe, the young, old and infirm succumbed to the smog and weather; around 20,000 extra deaths occurred in England alone. Signs of this cull may be gleaned by a visit to a graveyard. I went over to one nearby and the first two gravestones I encountered both recorded deaths in late 1783. Coincidence? Probably, but as the authors warn, the impact of the next Icelandic blast may ruin far more than a few package holidays.

**GILES SPARROW** is a science writer and the author of *Physics In Minutes*


## Nanoscience

**Giants Of The Infinitesimal**

**Peter Forbes and Tom Grimsey**

Papadakis

It is 55 years since the great American physicist Richard Feynman speculated on the potential to build objects a few atoms across. Since then, it might seem that nanotechnology has gone nowhere. We've heard more about fictional nanobots rebelling as all-consuming 'grey goo' than wondrous new tech. But Nanoscience demonstrates that there have been many remarkable developments.

The early prophets of nanotechnology assumed it would involve tiny but traditional feats of engineering. However, on the scale of cells and large molecules, different forces apply. Forbes and Grimsey take us through the importance of self assembly, learning from nature's ability to make complex structures from simple instructions, then go on to discuss graphene and the possibilities for nanomedicine.

However, the images, while striking, are poorly laid out and the flow of a good popular science book is missing. Instead you are bombarded with facts and artistic interpretations. Nanoscience has great content, but is let down by the presentation.

**BRIAN CLEGG** is the author of *Dice World: Science And Life In A Random Universe*

# Time Out

## In the know

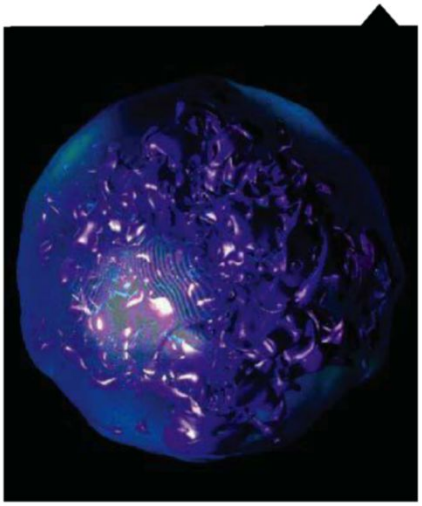
SET BY DAVID J BODYCOMBE

**1** **A bizarre quacking sound heard in the Southern Ocean for 50 years has been revealed as what?**
a) The underwater callings of Antarctic minke whales
b) The sound of ice calving from glaciers
c) Sonar chirps from nearby submarines

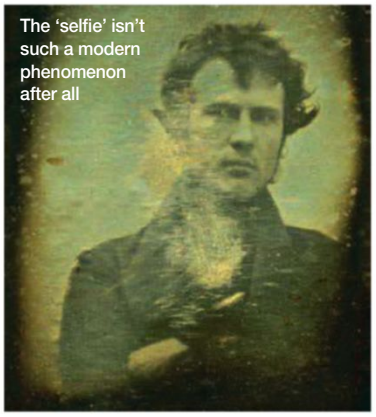
**2** **Scientists in the UK and Ireland have made graphene using which common household appliance?**
a) Kitchen blender
b) Vacuum cleaner
c) Electric iron

**3** **Between 2000 and 2013, the Comprehensive Nuclear-Test-Ban Treaty Organization detected how many explosions on Earth caused by asteroid impacts?**
a) 6
b) 16
c) 26

**4** **This image shows a computer simulation of what cosmic event?**
a) A supernova
b) The Big Bang
c) A gamma-ray burst



**5** **In what year was this photograph – the first ever 'selfie' – taken?**
a) 1779
b) 1839
c) 1899



The 'selfie' isn't such a modern phenomenon after all

**6** **Complete the recent headline: "Men's beard fashions guided by _____"**
a) Sunlight
b) Hormones
c) Evolution

**7** **What's the name of the social Q&A app launched earlier this year by Twitter co-founder Biz Stone?**
a) Jelly
b) Cream
c) Custard

**8** **Scientists have discovered what could be the birth of a new moon around which planet?**
a) Mars
b) Saturn
c) Mercury

**9** **Scientists have found that blood inside an elaborately decorated gourd probably didn't belong to which beheaded person?**
a) Marie Antoinette
b) Louis XVI
c) Charles I

**10** **What's unusual about the cave-dwelling insect Neotrogla?**
a) The males eat their own faeces
b) The females have penis-like sex organs
c) The juveniles are bigger than the adults

**11** Complete the recent headline: "_____ have structurally different brains"
a) Monkeys
b) Lawyers
c) Artists

**12** Which of these items wasn't contained in a recent cargo shipment to the International Space Station?
a) Clean underwear
b) Microbes from a T. rex fossil
c) A set of robotic legs

**13** What caused this red Moon, photographed in California in April?
a) Outgassing from the Moon's craters
b) Air pollution
c) A total lunar eclipse

This sight is called a 'blood Moon' – but what causes it?

PHOTO: US LIBRARY OF CONGRESS, TOM RUEN/WIKIPEDIA, ADAM BURROWS/JASON NORDHAUS/PRINCETON UNIVERSITY

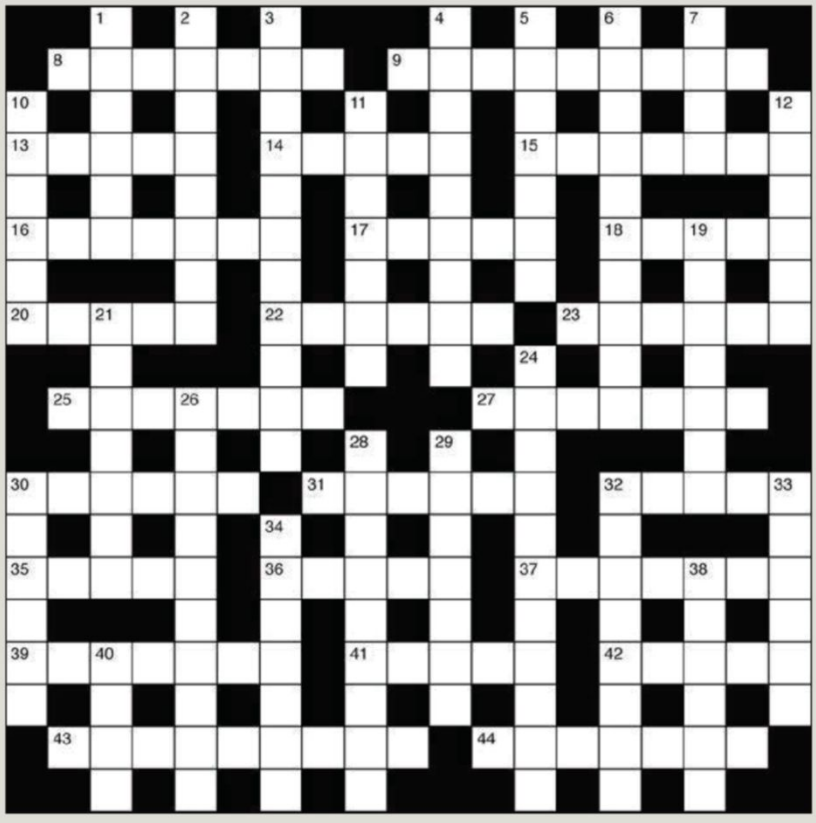
# Crossword No.165

## ACROSS

**8** Many not worried that it means the opposite (7)
**9** Dim dealer moved within hearing (6,3)
**13** Money for a large animal (5)
**14** Closest relative caught that fellow parking (5)
**15** Right to chat about alien – it has teeth (7)
**16** Musical right for mechanic (7)
**17** Classical moulding gives a sign, we hear (5)
**18** Route deviated to exterior (5)
**20** Copper has time to add flavouring (5)
**22** Patiently sorting out priorities (6)
**23** Divert rain by using base 2 (6)
**25** Depressed, perplex an Arctic creature (4,3)
**27** Brew causes commotion (7)
**30** Vices constructed with large attachment device (6)
**31** Policeman in his element (6)
**32** The best dairy product (5)
**35** Only application left for a dipper (5)
**36** Article about my hybrid herb (5)
**37** Overexcited to take on a particle (7)
**39** Key result about some stars (7)
**41** Harass a dog (5)
**42** Bishop joins first victim in the Tower (5)
**43** A new client working with one rock formation (9)
**44** Bird found in no Homer translation (7)

## DOWN

**1** Needing correction without Dutch machine (6)
**2** One dip soon affected pigment in the eye (8)
**3** Scorn thorny development of particle accelerator (11)
**4** Membrane paid off – note harm has moved round (9)
**5** Talk at a location (7)
**6** Import goes mad and shows growth with respect to gravity (10)
**7** Sailor returns to church composer (4)
**10** Soldier in cart accident – very sad (6)
**11** Attach appendage to duck (7)
**12** Level fable about additive (6)
**19** Student in a terribly spruce exterior, say (7)
**21** Frenchman sees everyone use wrong bone (7)
**24** Wasted rather toned figure (11)
**26** Flap about pig's toilet (10)
**28** College afterwards got point of plastic (9)
**29** Egypt pushes out Greek city (7)
**30** Coal spread around cavity (6)
**32** Rodent may pray a cab has been ordered (8)
**33** Fellow let loose below the crust (6)
**34** Antiseptic monster I learn about (7)
**38** Flexible game (6)
**40** Supporter of foul nature (4)
**37** Alternatively cultivate each vegetable plant (6)



## SOLUTION TO CROSSWORD 162

## QUIZ ANSWERS

1A, 2A, 3C, 4A,
5B, 6C, 7A, 8B,
9B, 10B, 11C,
12A, 13C

## HOWDID YOU SCORE?

0-4 Pulling a moonie
5-9 Reaching for the moon
10-13 Over the moon

*Last issue's solution was for crossword 161, we apologise for the labelling error.

# The Last Word

## It may not have held up, but the Steady State theory was a thing of beauty

The demise of something beautiful is an odd thing to celebrate. It's even harder to understand if that something is a scientific theory – for how can a theory be 'beautiful'? As with works of art, scientific beauty is a bit subjective. But I'd argue only total philistines could fail to see the beauty of a theory that died exactly half a century ago: the Steady State model of the Universe.

Born in the mid-1940s in Cambridge, it was the brain-child of some of the most original scientists of the last century, including Fred Hoyle – the greatest astrophysicist of his day. In essence, they argued that the Universe wasn't created in some messy 'big bang' billions of years ago (to use the derisive term Hoyle himself coined). Instead, it has existed forever, its expansion propelled by what we'd now call dark energy, which also created matter to keep the density of the Universe constant – and thus forever in a 'steady state'.

Even at the time, the Steady State theory generated controversy – stoked by personality clashes between its creators and their academic rivals. In the end, its critics proved right. In June 1964 two physicists at Bell Laboratories in New Jersey detected radiation from space with exactly the properties expected of the cooling embers of that messy Big Bang the Steady State model rejected.

Yet not everyone celebrated the demise of the Steady State theory. The late, great British cosmologist Dennis Sciama put it best, saying the theory had "a sweep and beauty that for some unaccountable reason the architect of the Universe appears to have overlooked".


With pretty much everyone now believing there was a Big Bang 14 billion years ago, such hand-wringing may sound quaint. But Sciama's aesthetic arguments still hold up. Most obviously, the Steady State theory didn't give rise to awkward questions about what existed 'before' the Universe. Less well known is the fact that the Steady State model had a key feature of beautiful things: symmetry.

**"I'd bet serious money on the Steady State theory emerging as the perfect description of the Multiverse"**

Most people regard symmetry merely as some kind of appealing regularity. But to theoreticians, it's far more profound. It gives them unchanging properties they can rely on to build models of reality. For example, they regard the Universe as having spatial symmetry; that is, on the grandest scales, it looks the same at all points and in all directions. But the Big Bang universe lacks one key symmetry. On the grandest timescales, it's not the same. It lacks temporal symmetry.

This is what makes the Steady State universe achingly beautiful to theoreticians: it's 'maximally symmetric'. On the largest scales, it looks the same in all directions – and at all times. Amazingly, all its properties can be worked out purely from this fact; you don't need to assume Einstein's theory of gravity, or anyone else's, to tell what it's like.

Too bad, then, that it's wrong. Or is it? Half a century after its demise, there's huge interest in the idea that – on the grandest scales – our Universe is just a speck in a truly infinite Multiverse, with the Big Bang just one of a series stretching back into the infinite past. I'd bet serious money on the Steady State theory emerging as the perfect description not of our clunky Universe, but of the Multiverse, in all its maximally symmetric beauty.

Sadly, I probably won't be around in 2064 to collect my winnings. But remember - you heard it here first.

**ROBERT MATTHEWS** is Visiting Reader in Science at Aston University, Birmingham

ILLUSTRATOR: JAN VAN DER VEKEN

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## HIGHLAND

Nepenthes Rajah is the biggest pitcher plant in the world.

= 8

The longest insect in the world is the stick insect from Sabah.


Montane horned frog is the most camouflaged frog species in Borneo resembling ninjas of the forest!

Rafflesia, the world's largest flower can grow up to 90cm in diameter.

Rothschild's Slipper Orchid is the most expensive orchid in the world.

The Bornean Falconet stands as the smallest raptor in the world.


Kinabalu Park is almost as big as Singapore!

≈

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Learn more about Sabah's RAINFOREST in the next issue.

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